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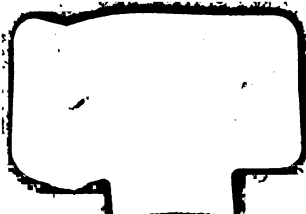
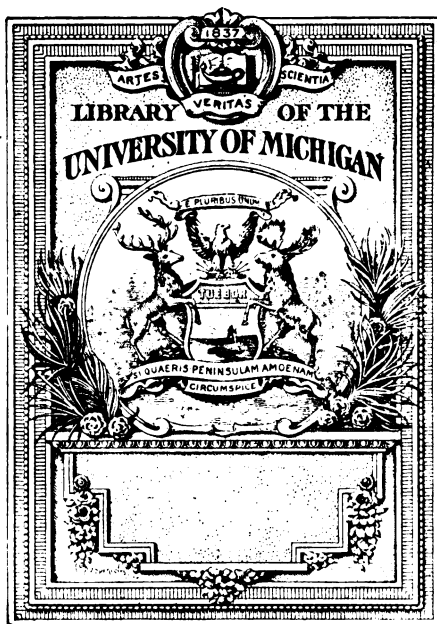
THE ONYX MARBLES:
THEIR ORIGIN, COMPOSITION,
AND
USES, BOTH ANCIENT AND MODERN.

BY

GEORGE P. MERRILL,
Creator of the Department of Geology.

From the Report of the U. S. National Museum for 1893, pages 259-285, with plates 1-48.

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THE ONYX MARBLES: THEIR ORIGIN, COMPOSITION, AND USES, BOTH ANCIENT AND MODERN.

By **GEORGE P. MERRILL.**
Curator, Department of Geology, U. S. National Museum.

"It now remains for us to speak of stones, or in other words, the leading folly of the day; to say nothing at all of our taste for gems and amber, crystal and murrhine vases. For everything of which we have previously treated (down to the present book) may by some possibility or other have the appearance of having been created for the sake of man; but as to the mountains, nature made these for herself, as a kind of bulwark for keeping together the bowels of the earth; as also for the purpose of curbing the violence of rivers, of breaking the waves of the sea, and so, by opposing to them the very hardest of her materials, putting a check upon those elements which are never at rest. And yet, we must hew down these mountains, forsooth, and carry them off; and this for no other reason than to gratify our luxurious inclinations."—PLINY.

Since very early times civilized man has shown an ever increasing tendency to decorate his home and his temples with objects beautiful and rare. With but a limited knowledge of metallurgy, with methods of manufacture crude in the extreme, the scope of his means was at first limited to such materials as nature had already prepared for his use or as could be wrought into objects of beauty by the few arts at his command. It is but natural, therefore, that the gems and precious stones early came into demand for household as well as personal adornment, while the marbles and alabasters, the granites, porphyries, and more vulgar lime and sandstones became equally desirable for purposes of interior decoration and for the rougher exteriors of houses and palaces, temples and tombs, wherever civilization had gained sufficient foothold to render them objects of admiration, or where a desire for immortality had spurred the builder to seek a less perishable material than wood.

Hence it is that the onyx and sardonyx, the diamond, the opal, and the pearl, as well as marbles and alabasters were thousands of years ago as well known and—among the wealthier classes—even more universally used than to-day. It is indeed a singular fact that in all these years that have elapsed since history began, scarcely a gem or ornamental stone of more than local importance has been discovered but was known, in at least some of its varieties, and utilized by a people so ancient that we can read their history only in their ruins.

Among the most beautiful of the many stones thus used for both building and for interior decoration, were certain travertines and cave

deposits, the so-called onyx marbles, or oriental alabasters, the *lapis oniscus*, or *onychites*, of the Romans. It is the purpose of the writer to present herewith in considerable detail the results of his own researches and observations on this class of rocks, together with so much additional information as can be gleaned from available sources.

It is unfortunate in our discussion of the subject in hand, that both the popular names by which these stones are known are erroneous and misleading. The term onyx as properly used, includes a banded variety of chalcedony—a purely siliceous rock—the name being derived from the Greek *ονυξ* or *ονυχιον*, a nail, in allusion to the wavy bands by which the stone is traversed, and its translucency, both of which are characteristics of the nails upon the hand. That such a name should have become applied to this particular variety of travertine is by no means strange, since both the characteristics of banding and translucency are often as pronounced as in the true onyx. And, inasmuch as the name has become too firmly engrafted upon the literature to ever become wholly eradicated, it is the name used here, but in its adjective form only, as descriptive of a kind of marble.

The term alabaster as applied to the stone is even more misleading than onyx, since both stones are used for much the same purposes, and when reading published accounts we are not infrequently at a loss, unless descriptive qualities are mentioned, to know at all times whether the material under discussion is a true alabaster (gypsum) or an onyx marble. Thus Chateau * states that the alabasters are translucent, of a greater hardness than the marbles proper, and are hence more expensive to work. Finally he says the alabasters “présentent des veines festonnées et onduleuses, que l'on ne remarque jamais dans les marbres avec cette même irrégularité.” It is obvious that this is a travertine and not a true alabaster. Again (on p. 453) he speaks of “*L'alabatre dur*,” or “*calcaire*,” having a yellow or variegated tint, and which is found in grottos and caverns in calcareous rocks. The “*alabatre tendre*” or “*gypseux*” of this writer is the true alabaster.

Pliny, the elder, from whom we quoted at the beginning of this article, wrote with an equal lack of perspicuity, though this perhaps is to be little wondered at. He says: “Our forefathers imagined that onyx was to be found only in the mountains of Arabia, and nowhere else, but Sundines was aware that it is also found in Carmania. Drinking vessels were made of it at first, and then the feet of beds and chairs. Cornelius Nepos relates that great was the astonishment when P. Lentulus Spinther exhibited amphoræ made of this material, as large as Chian wine vessels in size, ‘and yet five years after,’ says he, ‘I saw columns of this material, no less than 2 and 30 feet in height.’ At a more recent period again some change took place with reference to this stone,

* *Technologie du Batiment*, Vol. II, p. 448.

for four small pillars of it were erected by Cornelius Balbus in his theater as something quite marvelous. Ajassen, however, thinks these were of yellow jasper or sardonyx, and I myself have seen 30 columns of larger size in the banqueting room which Callistres erected."

Again, "this stone is called 'alabastrites' by some, and is hollowed out into vessels for holding unguents, it having the reputation of preserving them from corruption better than anything else. In a calcined state it is a good ingredient for plasters. That which is of a honey color is the most esteemed, covered with spots curling in whirls and not transparent. Alabastrite is considered defective when it is of a white or horn color, or approaching to glass in appearance."*

"Alabastrites is a stone which comes from Alabastron in Egypt and Damascus in Syria. It is of a white color, spotted with various tints. Calcined with fossil salt and pulverized, it is a cure for affections of the mouth and teeth, it is said."†

"Ajassen remarks that under this name (alabaster) the ancients meant, first, yellow, calcareous alabaster, and, secondly, chalcedony, unclassified."‡

It seems most probable that the drinking vessels and feet of chairs and beds referred to in these quotations were of the true onyx (chalcedony). The amphoræ and large columns, on the other hand, were most likely of the onyx marble (travertine or stalagmite). The alabastrites, which on being calcined is good for plasters, would seem at first thought to be a true alabaster (calcium sulphate) since this when thus treated yields the well-known plaster of paris. I have as yet, however, to learn with absolute certainty of the use of the sulphate by the Egyptians for the purpose he mentions—that of making vessels for holding unguents; and, inasmuch as the calcium carbonate would yield quicklime on calcining, it seems most probable that the material referred to in the second and third quotations from Pliny's work was of the last-named material.

In the descriptions of St. Marks Cathedral at Venice, as given by Baedeker and others, mention is made of an altar with "four spiral columns of alabaster, said to have once belonged to the temple of Solomon, of which the two white ones in the middle are semitransparent." To one at all acquainted with the physical properties of the true alabaster it seems impossible that the material can be other than an onyx marble or perhaps chalcedony.

The above illustrations together with the references which follow will serve to show the confusion existing in the literature on the subject.

The derivation of the name is interesting, and may well be dwelt upon briefly here. The original Greek word from which our word

* Pliny, Natural History, Book xxxvi, chap. 12.

† *Ibid.*, Book xxxvii, chap. 54.

‡ *Ibid.*, Vol. vi., p. 399.

alabaster was derived was *αλαβαστρος*, or *αλίβαστρον*, and is said to have been derived from *α*, not, and *λαβή*, a handle, or *χαβεῖν*, to hold, in allusion to the little handleless, phial-like, or amphora-shaped perfume vessels constructed from it. But the word after a time passed from the thing made to the substance of which it was made, though Pliny mentions an Egyptian town called Alabastron, where the manufacture of the vessels was carried on. The ancient Roman name of the stone was *alabastrites*.* Be this as it may, the name alabaster, as now used by all authorities, applies only to a white, though sometimes variously veined and mottled variety of gypsum, a calcium sulphate, while the onyx marbles with which we have to do in this work, are of calcium carbonate and mineralogically either aragonite or calcite, principally the latter.

ORIGIN AND MODE OF OCCURRENCE.

The origin of these stones is purely chemical, and of interest on account of the very simplicity of the process. Simple and well known though it may be, we are apparently not yet able to account in a manner entirely satisfactory for the varying physical conditions, as texture and hardness or form of crystallization, under which the material occurs. Pure water, although an almost universal solvent, nevertheless acts so slowly upon most substances belonging to the mineral kingdom that the results are quite inappreciable to the ordinary observer. When, however, holding minute quantities of carbonic acid, and especially when, as deep in the surface of the earth, it is under considerable pressure, its solvent property is very considerably augmented, and results are produced both in the way of solution and redeposition which are readily noticeable, even to the most casual observer.

One of the most common mineral substances found in aqueous solution is carbonate of lime, the essential constituent of ordinary limestones and marbles, as well as of the beautiful onyx marbles, as we shall notice later. It is to be found in the water of all springs, streams, lakes, and seas, and furnishes the means whereby the multitudinous shellfish and corals build up their calcareous shells and skeleton-like supports. Pure water will dissolve only 1 part in 10,800 when cold and 1 part in 8,875 when boiling. When the water is saturated with carbonic acid gas at ordinary atmospheric pressure and a temperature of 10° C., its capacity for solution is increased to nearly 1 part by weight in 1,000 (0.88 grams per liter of water). With an increase in pressure the amount of carbonic acid that can be held by water is also increased, and there is as a natural result an augmentation in its solvent power. The maximum amount of lime which can be dissolved, even under the most favorable circumstances, is stated by Roscoe and

*JONES, T. RUPERT. Demonstration on the marbles and other monumental stones in the British Museum.—(Proceedings Geologists Association, Vol. VIII.)

Schorlemmer to be about 3 grams per liter of water, or 3 parts by weight to 1,000.

As has long been known, it is to the escape from solution of half the combined carbonic acid, aided in some cases by the secreting power of algous vegetation, that is due the deposition of the lime carbonate in the form of sinters and tufas about the orifices of springs, in that of scale in steam boilers and other vessels, or in the form of stalagmitic and stalactitic deposits in caves. With its solvent power diminished by the loss of the acid gas, the water deposits its load as rapidly as the gas escapes.

Now, although we know this to be the process by which the calcareous deposition takes place, we do not know absolutely just what are the conditions which control the character of the deposit as regards compactness and condition of crystallization. Why in some cases the deposit should be so compact as to be susceptible of an enamel-like polish, and of such colors as to make a beautiful marble, or again light and tufaceous like those now forming at the Mammoth Hot Springs in the Yellowstone National Park, or the more compact *lapis Tiburtinus* of Tivoli, Italy. Such synthetic work as has been done fails to throw much light upon the subject. G. Rose* has shown that by humid methods it is possible to produce out of the same solution crystals of both aragonite and calcite, the one or the other forming according to the temperature of the solution. Aragonite was formed exclusively by a rapid evaporation of hot solutions, while calcite was produced from similar solutions, both hot and cold. As the investigations here chronicled have shown the onyx marbles to be almost invariably of calcite, it is at once evident that we must look for other controlling conditions than those of temperature for a satisfactory solution. Such literature as bears upon the subject enables us, however, to draw, from analogy, certain conclusions, and it may not be without interest to refer here briefly to the expressed opinions of others. Thus Dr. Edward Hitchcock, writing half a century ago, says: †

"I have alluded to the deposition of marble, or alabaster, by certain springs in the vicinity of Lake Oroomiah (Persia). What is called the Tabrez marble has been repeatedly described by travelers; but I doubt whether definite geological ideas have yet been entertained respecting the mode of its formation. With the exception, perhaps, of a deposit of travertine around Rome, in Italy, resembling statuary marble, I am not aware of any case besides those around Oroomiah in which the most beautiful marble is produced by springs. The Tabrez marble is usually of a yellowish or light blue color, perfectly compact, and so translucent that it is used in thin slices for the windows of baths and other places, like the phengites of the ancients. * * * The common opinion is that the springs now deposit it; but one or two facts have led me to suspect that this may not be the case. Above the marble there lies a deposit, several feet thick, of common tufa, or travertine. Now, my suspicion is that this tufa is all the deposit which has been formed since the springs

* Fouque and Levy, *Synthèse des Minéraux et des Roches*.

† *Transactions of the Association of American Geologists and Naturalists, 1840-'42, pp. 414-415.*

assumed their present state, and that the alabaster was deposited when their temperature was higher, and when, perhaps, they were beneath deep waters. However, this opinion is little better than conjecture."

Bischoff,* in discussing similar phenomena, says:

"It is interesting to know that mineral springs can deposit granular limestone. I doubt whether hot springs are better suited to this than cold, from which the deposition takes place slower than from the former; but the slower the CaCO_3 is deposited, the more likely is it to assume a crystalline form."

J. L. Smith, writing of the thermal waters of Hierapolis, says: †

"The amount of water is very great, and it is so highly charged with carbonate of lime as to incrust all bodies that it comes in contact with, and it takes place so rapidly that the concretion does not possess great solidity, and frequently has a granular form, resembling driven snow."

W. H. Weed, in writing on the deposition of calcareous matter by the waters of the hot springs of the Yellowstone National Park, says: ‡

"Another variety * * * is that which forms the lining of hot-spring ventholes. This is deposited comparatively slowly, and occurs in shelly layers half an inch to 3 inches thick, with a smooth, rounded, and globular surface. It is crystalline and marble-like and pure white. This travertine is a crystallization out of a supersaturated solution of carbonate of lime, due to the relief of pressure as the waters approach the surface. A similar deposit lines the ventholes of the Orange and other springs, and is analogous to the deposit so quickly formed in the conduit pipes leading the hot water to the hotel baths, also due to supersaturation, experiments showing that such solutions do not deposit their excess of lime at once, but in the course of a short time."

Bearing in mind that these onyx marbles are of calcite, and so compact as to acquire under proper manipulation an enamel-like polish, and further that, as noted later, they are all superficial deposits, it remains to formulate our own opinions regarding their origin and to note how far they differ, if at all, from those above given. It is well to note, at the very outset, that while there is no apparent doubt but that, with the exception of the deposits in caves (see p. 550), the onyx marbles are the result of spring action, I have been able to learn of no single instance in which material of this nature is now forming, the recent deposits invariably taking a tufaceous structure. It is singular, to say the least, that widespread phenomena due to purely local causes should be so nearly synchronous in action and that we should be living in an age of cellular deposition only.

It is evident that, so far as their mineralogical nature is concerned, the onyx marbles may be products of deposition from water of any ordinary temperature, hot or cold. Accepting the fact that such deposition would take place more slowly from a cold than from a hot solution, and that the more slowly deposition takes place the more likely is

* Chemical and Physical Geology, Vol. I, p. 152.

† Original Researches, p. 64.

‡ Formation of Travertine and Siliceous Sinter by the Vegetation of Hot Springs. Ninth Ann. Rep., U. S. Geological Survey, 1887-'88.

the deposit to assume a crystalline structure, we might at first thought conclude these to be cold rather than hot water deposits. Bearing in mind, however, that they bear evidence of comparatively rapid growth, such as would indicate deposition from waters of a high degree of saturation, it would seem more probable that at the time of issuing the waters were comparatively hot, and perhaps under conditions of considerable pressure as well as saturation.* The tendency of such to immediately lose their excess of carbonic acid and deposit a light tufaceous travertine or sinter, as upon the immediate surface at the Mammoth Hot Springs, would be checked provided the discharge took place in pools of quiet water. We know that deposits sufficiently compact to receive a polish are sometimes formed in steam boilers, where, however, more than ordinary degree of saturation prevails and under unnatural conditions of pressure.† The onyx deposits being, however, purely superficial, no such conditions of pressure could exist, and we must apparently fall back upon such conditions as should retard the loss of carbonic acid and thus cause the deposit to take place more slowly. Such conditions, we may fairly assume, would exist at the bottom of pools of water, and it is under such conditions, in the writer's opinion, based upon observation as well as on theoretical grounds, that the onyx marbles have been formed. To account, then, for the alternating tufaceous and compact character of the beds which everywhere exists, we have to make only the natural assumption that the temperature of the water and its degree of saturation periodically varied, the variation being accompanied perhaps by a difference in volume or place of discharge, whereby the water hitherto accumulating in pools, ran off almost immediately, permitting a rapid loss of carbonic acid and an equal rapid diminution in temperature. This intermittent character of the deposition, and in fact the general history of onyx formation is, so far as my own experience goes, best shown in a region rather difficult of access known locally as the Tule Arroyo, a deep cañon or ravine on the peninsula of Lower California, some 150 miles south from San Diego, and 15 to 20 miles from the gulf coast. The country rocks here are nearly black mica schists and blue gray silicified limestones and quartzites standing nearly vertical with a strike some 20° west of north, the whole being cut by the ravine, or arroyo, as it is called by the Mexicans. On the steep slopes of the hills on either side, and before the ravine had assumed anything like its present depth, springs have from time to time gushed out and deposited their calcareous load upon the surface over which they flowed. As a rule the first material

*The fact that nearly every deposit of this nature of which I have thus far found trace is in a region of comparatively recent volcanic activity increases the probability of their being hot-spring deposits.

†The writer has in his possession such a crust some 5 c. m. in thickness, taken from the boiler of an ocean steamer plying between New York and Portland, Me. In this case, however, the mineral is anhydrite (anhydrous sulphate of lime) rather than a carbonate.

thus deposited was a dull-colored cellular travertine which cemented together the angular fragments of older rocks with which the slopes were strewn, giving rise to a coarse conglomerate, or breccia. After this had gone on for some time and the travertine layer had grown, it may be, to several feet in thickness, the conditions changed as I have attempted to outline above, and the deposit took the form of the compact and beautifully veined and tinted stone to which the name onyx is commonly applied. In time the onyx-forming action ceased in its turn, and for a period no calcareous deposition whatever took place, the slopes becoming once more covered with angular particles of older rocks from higher up, these in their turn becoming cemented into breccias when the springs resumed their work. In this way were built up the alternating layers of breccia, tufa, and onyx, until finally all deposition practically ceased, and spasmodic but fiercely rushing streams cut the arroyo to its present depth, exposing in either wall the irregularly alternating beds described. In the bottom of the cañon still exist two diminutive springs, each building up in its feeble way small beds of tufaceous material. The water still flowing is so highly carbonated as to bubble like a glass of Vichy fresh from the fountain, and leaves, when drank immediately, a pleasant prickly sensation in the mouth and throat.

In discussing the origin of the onyx marbles, it is perhaps but fair to question the possibility of their having been originally deposited as tufaceous materials, and subsequently compacted and crystallized by pressure, heat, and percolating solutions, or other of the ordinary agents of metamorphism. This can be best answered by pointing out the alternating character of tufaceous and compact layers. It is difficult to conceive of conditions such as should have metamorphosed any one bed without affecting, in the least, those either above or below, or both. The wavy, undulating lines of deposition, comparable with the rings of growth upon a tree, are well defined and unbroken, and though differing frequently from one another in color and crystallization preserve their parallelism and individuality throughout. (See pls. 1 and 3.) There are apparently good reasons for supposing the material to have been deposited as we now find it, the crystallization being contemporaneous with deposition, as is the case with the stalagmitic material in caves.* The wonderful variations in color, even in the same block or slab, are, however, in part due to changes subsequent to their deposition, and it may be well to dwell upon this branch of the subject in considerable detail. Few rocks possess so wide a range of colors or shades of the same color. Pure white, opaque, milk or chalk white to almost colorless, gray, brown in hues from light ochre to deep mahogany, buff, amber, ochre yellow, pink, red, and green are all common; the

* These latter deposits do, however, in some cases undergo a recrystallization whereby the whole internal structure is modified without change of external form, as I have mentioned elsewhere.

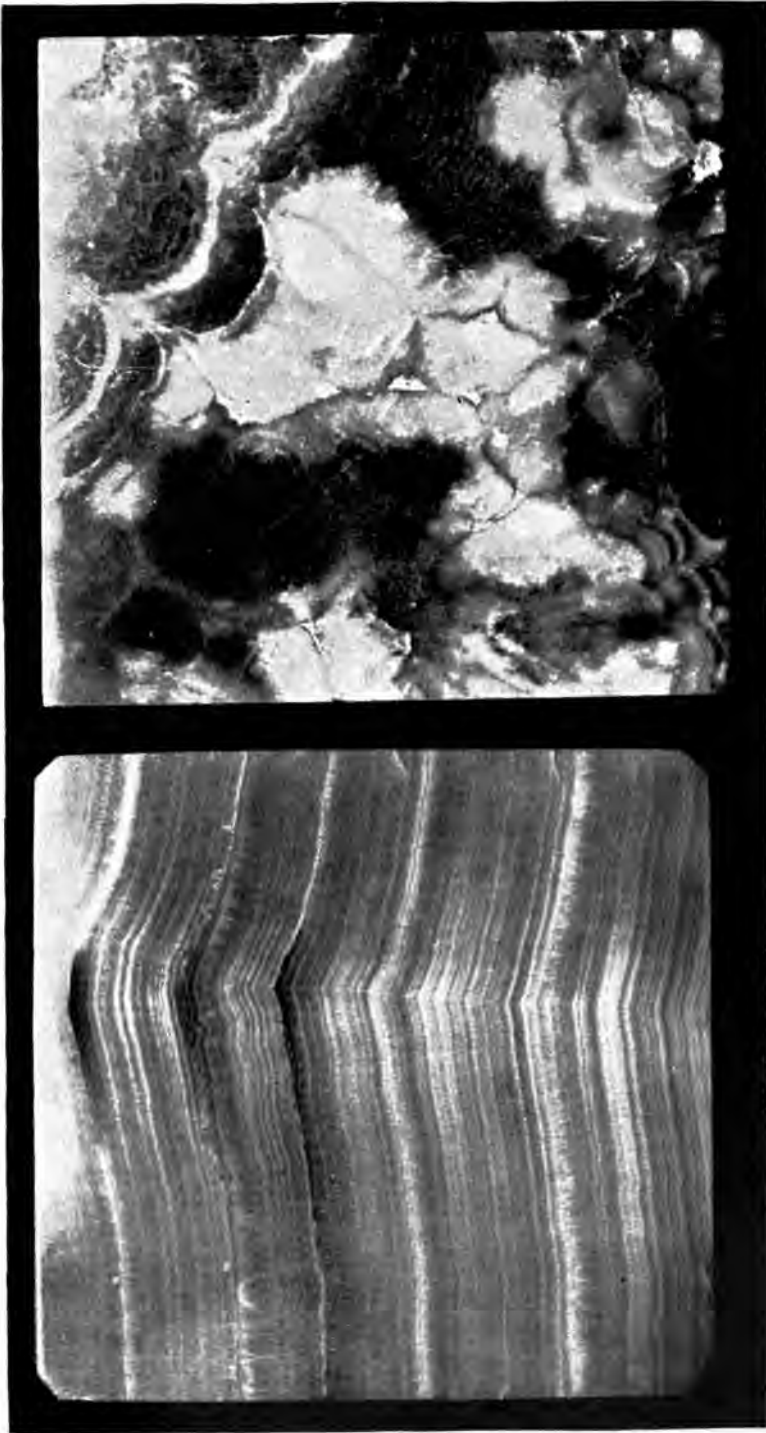
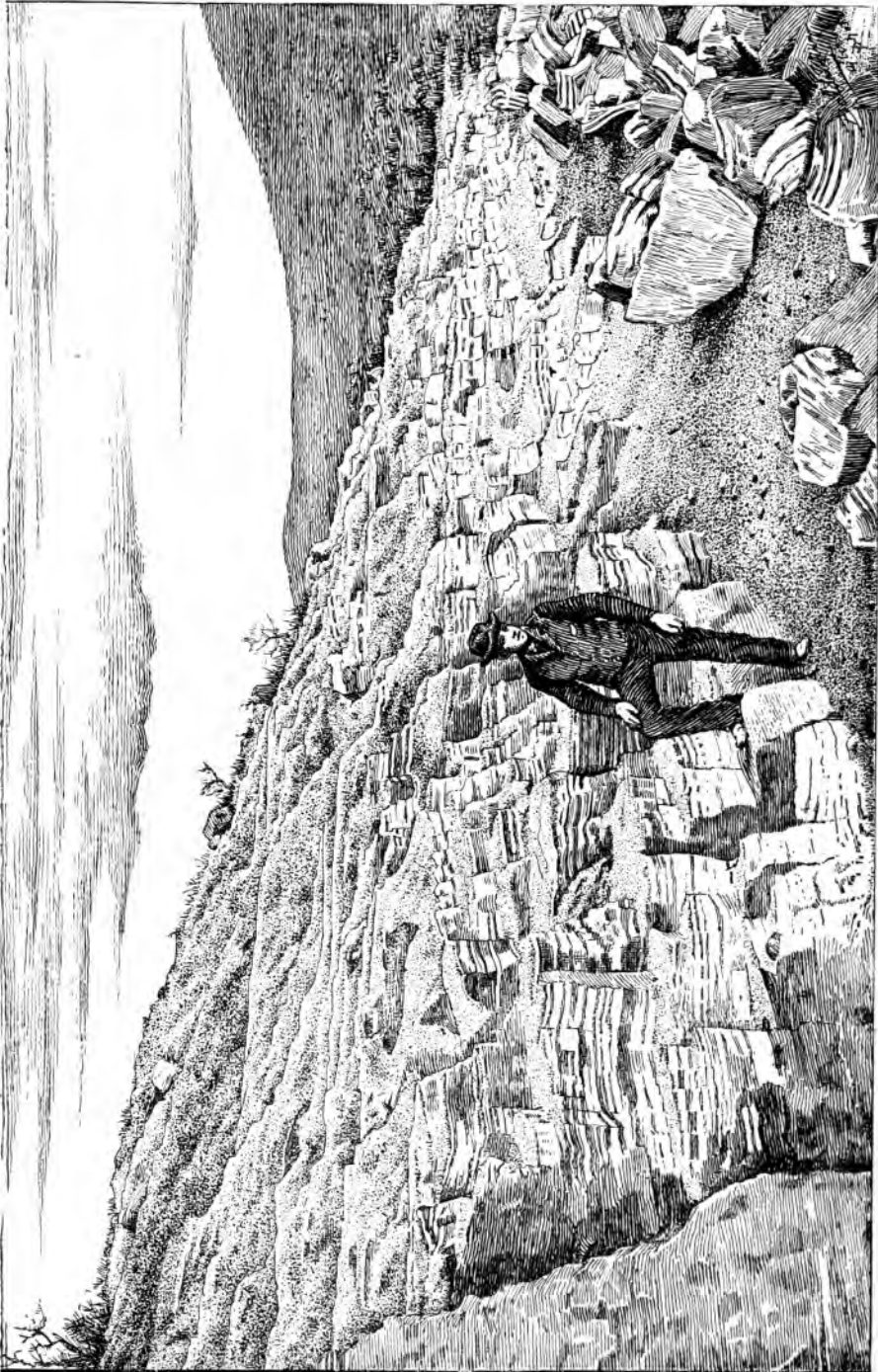


Fig. 1. Section across plane of deposition. Cat. No. 37640, U. S. N. M. Mexico. Fig. 2. Section parallel to plane of deposition. Cat. No. 28698, U. S. N. M. Italy.

ONYX MARBLES.
Natural size.



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CUT IN HILLSIDE SHOWING LAYERS OF TRAVERTINE, MAYERS STATION, ARIZONA.
Drawn from a photograph.

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SLABS OF ONYX MARBLE CUT ACROSS PLANE OF DEPOSITION TO SHOW BANDING.

Cat. No. 67000, U. S. N. M. Mayers Station, Arizona.

The colors are white, greenish, and brown.

U of M

various hues being sometimes constant throughout large masses, sometimes intermixed and blended, sometimes occurring in alternating parallel bands, and sometimes in distinct veins and spasmodic dashes. In the majority of cases the coloring matter is supposedly iron in some of its forms, aided in part by manganese; in any case the apparent color may be modified by conditions of crystallization and structure, a clear translucent stone, by transmitted light, appearing much lighter and of more delicate tints than one that is opaque.* Assuming that the color constituents are only the two metals named, it yet remains to account for their presence and explain the conditions under which they give rise to such a variety of hues. It is easy and presumably correct to assume that the coloring matters were deposited contemporaneously with the calcite, but we must not in accepting this overlook the fact that these substances are unequally soluble, and under proper conditions would not be deposited together at all, but would undergo a process of natural separation. As is stated by Bischof,† water which contains carbonate of lime and protoxide of iron “may, when it passes for long distances in contact with the air, finally deposit pure carbonate of lime.” This, for the reason that the iron early becomes converted into the condition of sesquioxide and is deposited almost at the start. We can here account for their intimate association only on the supposition that at the time of deposition the water was not flowing, but lying in quiet pools where oxidation as well as loss of carbonic acid was retarded. The variation in color of the bands might thus be in part accounted for on the supposition that the waters, as they issued, contained at times varying amounts of the oxides mentioned. (See pl. 3). ‡

In fact, however, the varying hues are by no means due wholly to the proportion of metallic oxides, but rather to the conditions under which these oxides exist and to organic matter. In certain cases, as in the slabs shown in pl. 3, the bands are of alternating white, green, and brown color, though all show practically the same percentages of iron when calculated as protoxide carbonate. As a matter of fact, however, the iron exists in this state only in the white and faintly

* A good illustration of the popular ideas regarding the cause of the color in these rocks is given in the accompanying paragraph from the *Engineering and Mining Journal* (New York), vol. 49, p. 678. “Mexican onyx is a form of stalagmite, and its colors are formed by oxides of metal in the earth over the caves through which calcareous water passes. Gold is represented by purple, silver by yellow, iron by red, copper by green, and arsenic and zinc by white.” It is difficult to conceive of any wording by which more errors could be comprised within the limits of a single paragraph.

† *Chemical and Physical Geology*, p. 146.

‡ The higher or the lower the temperature of the water, the more or less rapid its cooling, the greater or less abundance of bicarbonate of lime and protoxide of iron, and the different proportions in which these compounds occur—all these circumstances may give rise to the most varied deposits of these substances as regards their relative quality.—(*Bischof*, p. 147.)

greenish layers, the brown layers containing it in the form of both protoxide and more or less hydrated sesquioxides. Bischoff, in speaking of a like condition in the so-called sprudelstein of Carlsbad, says:*

The brown contains a considerably larger quantity of peroxide of iron than the white, which is sometimes quite free from it. This difference presupposes either that there is a difference in the quantity of iron contained in the water, or that sometimes the atmospheric air has a greater influence than at others, and that in those cases a larger quantity of protoxide of iron is peroxidized.

In the case of the stones here described the percentage of iron in the green and brown and red varieties is nearly the same, the varying hues depending mainly upon its chemical condition. While it is possible that a part of the change from protoxide carbonate to sesquioxide took place at the time of deposition, a large part is due to oxidation, which has taken place since the beds were in substantially their present condition, and is due to percolating solutions. That this is the case is abundantly proven by the fact that the oxidation in most cases can be readily seen to have progressed along lines of jointing and fracture and along the more porous layers. In many cases the oxidation is accompanied by a partial removal of the lime carbonate, whereby the stone is rendered cellular and unfit for use. Such, however, is not always the case, and many of the oxidized varieties are beautiful in the extreme, as well as unique. (*See under chemical and physical properties, p. 558.*)

The cave marbles differ from the travertines mainly in method of deposition, being cold-water deposits upon the walls and floors of limestone caves. Rain water passing through the atmosphere and soaking through the layer of soil by which the earth is covered becomes charged with a varying amount of carbonic acid, which gives it the power of dissolving slowly the lime carbonate forming the essential constituent of the rock limestone, as already noted. Filtering downward through cracks and fissures or between the laminae composing the beds, it thus gradually enlarges them until what are popularly known as caves or caverns are produced. But after this cave-forming process has gone on for awhile another process sets in, whereby the cavern may be wholly or in partrefilled. The water from the surface percolating down through the roof of the cave dissolves out a portion of the lime carbonate, just as when running through a crack or fissure, but in this case the water comes through the overlying rock and remains for a time suspended, in the form of a drop, from the ceiling. Here it evaporates or loses a part of its carbonic acid, and, unable longer to hold the lime in solution, begins to deposit it in the form of a ring around the outer margin of the drop. As time goes on this ring becomes prolonged into a quill-like tube, growing in length always from its lower end. After a time, as a rule, this frail tube becomes partially or wholly closed, when the water flows down over the outside, the growth now being wholly

* Op. cit. p. 148.

external. In this way are formed the elongated pendant cones from the roofs of caves, and to which the name stalactite is given.* Such on being cut and polished show a beautiful zonal structure, not wholly unlike the rings of growth upon the trunk of a tree. (Pl. 13.)

But it rarely happens that all the water evaporates upon the ceiling; a portion usually falls upon the floor, where by a similar process it builds up a deposit chemically the same as the stalactites, but differing in that owing to the spreading out of the water as it falls, the floor deposits are more massive in form. To these floor deposits the name stalagmite is given. In some cases they rise in the form of blunt trunks or cones to meet their corresponding stalactites above until there are formed continuous pillars from floor to ceiling, as shown in plate 4. If this process goes on for a sufficient time the entire cave may be refilled, and since the water in percolating through the roof dissolved only the pure lime carbonate, or with but a trace of impurity, leaving nearly all the carbonaceous, siliceous, and clayey constituents behind, so these stalactitic and stalagmitic deposits are of purer lime, refined by nature's methods and recrystallized under new conditions. The form of crystallization, it should be stated, is sometimes that of aragonite, but so far as the writer's experience goes, more commonly that of calcite. It is sometimes, though not always, possible to distinguish between the two forms of crystallization by the unaided eye, stalactites (or stalagmites) of aragonite showing interiorly a radiating fibrous structure, the fibers being not infrequently beautifully curved and of a silky luster, while those of calcite are more granular. It sometimes happens that deposits of both kinds are to be found in the same cave, though so far as my own observation goes they belong in such cases, as at Wyandotte, Indiana, to different periods of growth. What the conditions are upon which these varying forms of crystallization depend is not now apparent.

It follows almost from necessity from their mode of origin, as above given, that the beds of onyx marbles, both spring and cave deposits, are as a rule far less extensive and regular in their arrangement than are the ordinary stratified and bedded limestones and marbles. Spring action is more or less intermittent, and the place of discharge, as well as the character of the deposit, variable. The latter usually take the form of a comparatively thin crust, conforming to the contours of the surfaces on which it lies. The various layers thicken and thin out irregularly, and are often lenticular in cross section. Sound and homogeneous layers of more than 20 inches thickness are not common. Where two or more layers, of sound and merchantable material occur they are not infrequently separated by tufaceous material, foreign debris, or by impure and porous onyx of little value. This condition of affairs will become more apparent as particular occurrences are

* On the Formation of Stalactites and Gypsum Incrustations in Caves. Proc. U. S. Nat. Museum, xvii, 1894, p. 77.

described. The cave marbles vary even more irregularly, both in extent and quality. The deposit may be a mere veneering over the face of the rock, and although there is apparently an abundance, judging from appearances alone, the actual amount of available stone may be extremely small.* Moreover, such deposits are rarely uniform for any great distance, either in texture or color. Owing to coarse crystallization, they fracture easily, and, moreover, are more than likely to contain numerous cavities, large and small, known popularly as "thumb holes" and "pin holes." The small amounts of metallic oxides and organic matter they contain render the colors light and usually dull. White, yellowish, amber, and reddish, with a resinous luster, are common. The rock as a rule is less translucent than the true onyx marble, and when polished appears "muddy" and unsatisfactory. Nevertheless, such deposits do not infrequently yield comparatively small blocks of beautiful material and material that is doubly desirable because it is unique.

Properly managed such can be worked up to good advantage, but too much has been expected from them, and it is this fact that has led to the disastrous failures following every attempt that has thus far been made to work the cave marbles in America. If the material as taken from the ledge could be assorted by some competent person and worked up, each block for such a purpose of ornamentation as it seemed best adapted, then we might hope for some interesting results. But at best the cave marbles of America must rank as "uniques" rather than objects of commercial value. They will never become regular sources of supply. There is too much waste and too much uncertainty regarding amount and quality.

A marked and very beautiful feature of the onyx marbles in general, and particularly of those which originate as spring deposits, is the fine, undulating, parallel bands of growth or lines of accretion shown on a cross section, and which are of course due to its mode of origin through successive depositions upon the surface (see pl. 1). The stone owes its chief value for decorative purposes to its translucency, fine veination, and color. In many instances the original hues have become enhanced by oxidation and through the development of reticulating veins of small size, due to incipient fracture, into which percolating waters have introduced new coloring solutions or locally oxidized the protoxide carbonates, which seem to form the chief coloring constituent, as already noted.

The localities from which the finer grades of stone of this type have in times past or present been obtained are few and widely scattered,

* The writer has met with just such cases in his experience. A certain deposit was represented as a solid mass of merchantable stone, showing a quarry face 100 or more feet in length by some 20 or 30 feet in height. On inspection it was shown that the "quarry face" was but a thin coating of stalactitic matter over the sloping wall of an old cavern. Not a cubic yard of merchantable stone could have been obtained in the entire outcrop.



VIEW IN A LIMESTONE CAVERN SHOWING STALACTITIC AND STALAGMITIC MASSES.

PLATE 4.

100

and it is interesting to note that, with the exception of the cave deposit, all that have thus far come under the writer's notice which are of such color as to make them preeminently desirable for ornamental purposes, occur in hot and arid countries and regions not far distant from recent volcanic activity. This is as true of foreign as of American occurrences. It is to be noted that all the deposits known are of slight geological antiquity, belonging to late Tertiary and early Quarternary periods. If materials of like nature were earlier deposited they would seem to have so far lost their identity as to be no longer recognizable. Contrary to the general belief, as indicated in the literature of the subject, or by the labeling of samples in museums, the onyx marbles, as shown by the investigations here chronicled, are almost without exception of calcite and not aragonite. It is true that the basis for such a statement is founded mainly upon specific gravities, the results of which may in certain cases seemingly be open to doubt. While, however, it is possible that certain of these stones may be made up of finely alternating bands of calcite and aragonite, there would seem no legitimate reason for doubting the main mass of the material to be calcite, particularly when microscopic examinations have borne out the results obtained by gravity methods.

USES, ANCIENT AND MODERN.

As already noted, the onyx marbles were used in Egypt during very early times for making small articles, as jugs, bowls, canopic vases, and amphoræ, employed to hold offerings to the gods, the ashes of the dead, and for other religious and domestic purposes. We find them thus utilized as early as the second dynasty. It is worthy of note that few, if any, of these articles were polished, though many of them show great skill in workmanship. In the Abbott collection of Egyptian antiquities of the New York Historical Society are several fine examples of this nature, one of which is shown in pl. 9, fig. 2.

According to the guide book to the fourth Egyptian room of the British Museum (1892, p. 117) the vases, bowls, saucers, spoons, and other vessels, which were placed in the tombs to hold the wine, oil, honey, sweetmeats, perfumes, and cosmetics offered to the dead, were, during the first six dynasties, commonly made from plain white "alabaster" (whatever that may be). Afterwards, variegated marbles and stones were frequently employed, including aragonite, granite and diorite, steatite and schist. Mr. G. F. Harris states* that the onyx thus used during the earlier periods—the fifth and sixth dynasties—was plain and of one uniform layer, but about the time of the twenty-fifth dynasty a zoned variety of a yellow color came into use. This authority further states that the principal shapes shown in the British Museum are "hemispherical vases with wide open mouths, for holding wines; basins, cylindrical vases, with wide rims for unguents or oils; vases in the shape of wine jugs, two-handled amphoræ, and drop-shaped

* The Builder, London, vol. 61, 1891, p. 14.

alabasters." These latter forms were held in such high esteem that they were exported from Egypt, and it is stated that "the names of Persian monarchs have been found in hieroglyphic and cuneiform characters upon them, whilst vases apparently of Egyptian material, if not of Egyptian fabric, have been discovered in the early tombs of Asia Minor, Greece, and the isles of the Archipelago." According to other authorities,* the first mention of articles of this nature by Greek writers is that of Herodotus (born 484 B. C.), who speaks of a *μυρον αλβαστρον* as one of the presents sent by Cambyses to the Ethiopian king. "Some of these vessels," it is stated, "had a long and narrow neck, which was sealed; so that when the woman in the gospel is said to break the box of ointment, it appears probable that she only broke the extremity of the neck, which was thus closed." The Egyptians did not, however, confine their use of the stone to these small articles, but at a very early period began utilizing it for the interior decoration of their tombs and temples. According to Dr. J. W. Dawson,† the magnificent granite temple of Kephren at Gizeh was lined with this stone in the early age of the pyramid-building kings.

"Some of the very old tombs in the Memphite cemetery at Sakkarah are lined with alabaster, or partially so lined. A curious example of the latter may be seen in the tomb called that of Unas. The inner sepulchral chamber of this tomb is lined with slabs of alabaster. The work is then continued in common limestone, and the entrance of the tomb is lined with the stronger and more enduring red granite. At Abydos are the remains of a magnificent monolithic shrine of this stone, and at Karnak a similar shrine is built of alabaster slabs, some of them 20 feet in length. In this and other cases one is astonished that so fine work and material should be lavished on places enshrouded in darkness; and the question is raised, but can not be answered, What means of illumination had the ancient Egyptians, beyond the smoky oil lamps and torches, which would scarcely suffice adequately to illuminate the interior of tombs and temples, and would soon have destroyed their beautiful workmanship."

"The finest work in Egyptian alabaster that I have seen [says the writer] is the sarcophagus of Seti I, father of Rameses II,‡ found in his tomb in the 'valley of the kings,' by Belzoni, and now in Sir John Soane's Museum in London. It is 9 feet 4 inches in length, 3 feet 8 inches wide, and from 2 feet 8 inches to 2 feet 3 inches deep; and is hollowed out of a single block so delicately that its general thickness is only 2½ inches, and that a lamp placed within shines through the translucent sides. On the bottom of the coffin is a figure of Netpe, or Athor, the mother goddess, with arms extended to receive the body of the King; and the whole surface is covered with inscriptions and professional figures representing the liturgy of the dead. The lid was of similar character, but has been broken to pieces.§ By a singular combination of accidents, the mummy of this great King, which had been transferred by its guardian priests for greater security to Deir el Bahari, is now in the Boulak Museum. The noble sarcophagus prepared for it is in London, and his vast and beautifully decorated tomb stands open for the inspection of travelers in the 'valley of the kings.'"

* Smith, Dictionary of Greek and Roman Antiquities, 1890, p. 96.

† Modern Science in Bible Lands, pp. 283-286.

‡ Nineteenth dynasty. According to Mariette, 1462 B. C.; Prof. Lepsius, 1443 B. C. Still others give dates from 1350 B. C. to 1600 B. C.

§ A very complete account and a figure of this sarcophagus is given in the General Description of Sir John Soane's Museum, sixth edition, 1893, pp. 43-47.

The materials employed in the Temple of the Sphinx in Egypt are rose granite and "alabaster." The supporting piers are of granite, the lining slabs of the walls and the ceiling of "alabaster" without carving or any form of relief.

Onyx was also employed for statuettes, some few of which are preserved in the museums of to-day. The statue of Rameses, now in the Musee du Louvre, in Paris, is stated by Chateau to be of Egyptian alabaster, while in the Boulak Museum at Cairo are "alabaster" statues of Queen Ameneritis, mounted on a base of gray granite; also of Osiris, the scribes Neferhotep and Awi.

According to Hull,* a beautifully iridescent variety of the Egyptian stone was used in constructing the four columns, each about 8 feet in height, which adorn the Sala containing the cabinets of gems in the Galleria degli Uffizi at Florence. He also describes large cinerary urns formed from this material, one of the finest being in the museum of the Vatican at Rome, which measures 9 feet in length and 4 feet in depth. Also tables in the Galleria Pitti at Florence.

During the reign of Mohamed Ali, the founder of the present dynasty, onyx from the Beni-Souef quarries was largely utilized in the embellishment of the celebrated "Alabaster Mosque" at Cairo. This, it will be remembered, was partly completed in its present form by Said Pasha in 1857. The alabaster used for the incrustation of the masonry consists partly of blocks and partly of slabs. The beautiful yellow tint of the stone fades on prolonged exposure to the sun.† I am informed by Mr. H. A. Ward that the stone here used is so translucent that when the sun is shining upon it, shadows of passers-by upon the street are distinctly noticeable from within, even where the wall is 18 inches in thickness.

Following the Egyptians, the Romans, with their characteristic luxuriousness, did not fail to overlook so promising a material, and early adopted it for similar purposes. A portion of the vessels found in Grecian and Roman ruins are of undoubted Egyptian materials and manufacture. The quarries at Ain Tembalek were worked with great activity at a very early period by the Romans. This is proven not merely by the abundance of works of art in this stone among the Roman ruins, but also by the finding of actual quarry sites. In all the Arabian monuments found in the region, especially at Tlemcen, there has been frequent use made of the onyx. In the grand mosque Djama-Kebir, built during the twelfth century, may be seen the remains of an old court flagged with onyx, in the center of which is a fountain of the same material. In the mosque Djama-Abou'l Hassen, the numerous columns supporting the arcade are also of onyx. Beautiful examples of the character of the quarry product are also to be seen at Sidi Bon Medin and at the museum at Tlemcen. The onyx columns of the

* Building and Ornamental Stones, page 150.

† Baedeker, Guide to Lower Egypt.

ancient mosque of Mansourah are said to be particularly fine. Chateau states that the tunic of the statue of Diana in the Louvre is of the Algerian onyx. Material of the same nature, derived either from Algeria or the numerous caverns of Italy, was extensively utilized for sarcophagi by Romans, Etruscans, and Greeks, the body and cover in such cases being each of a single piece, and in many instances elaborately carved. The Etruscan sarcophagus in the Boston Museum of Fine Arts is of material of this nature.

Onyx from deposits near Lake Oroomia and Yezd was extensively used in the balmy days of the Persian Empire by the native nobles. I am informed by the Rev. Benj. Labaree that it has been used in the form of slabs to face the elegant fountains or to pave their baths. Small blocks were also used in the doors and windows of their baths in place of glass. "The most beautiful slab I know of," he writes, "is one some 8 by 4 feet, as near as I recall, serving as a table or sideboard in the English consulate at Tabreez. It must be some 4 inches thick. It is of a charming yellow tinge with darker reddish lines shading through it."

Writing on the same subject, the Rev. P. Z. Easton states that the grand staircase of the new palace of the Crown Prince at Tabriz is paved with this marble. In the bazaars one finds it employed by the lithographers. Small ornaments, such as saltcellars, vases, etc., are cut from it, and sometimes slabs for table tops. "In cemeteries it is used to some extent, but generally only where the cemetery is inclosed, as otherwise it is likely to be broken and carried off. In Moslem cemeteries, however, this is not so apt to be the case. I remember seeing a fine block at Marand, about 40 miles from Tabriz, which had not been disturbed." Mr. Easton further states that there must be some variation in quality, as in some cases stones which have been exposed even for a comparatively short period change in color and become comparatively valueless, "while in other cases, as in those of the magnificent slabs at the back of the Blue Mosque, which have stood for four centuries, and for a century or more have been more or less exposed to the action of the weather, there is comparatively little change." In ancient times, when there was more wealth in Persia, this stone was probably much more extensively used, and larger pieces were hewn out. A Persian prince of to-day would hardly incur the expense of moving such masses as the blocks in the Blue Mosque. Morier states* that the tomb of the Persian Poet Hafiz is also of this stone. He describes this as "a parallelogram with a projecting base, and its superficies carved in the most exquisite manner. One of the odes of the poet is engraved upon it, and the artist has succeeded so well that the letters seem rather to have been formed with the finest pen than sculptured by a hard chisel. The whole is of the diaphanous marble of Tabriz, in color a combination of light green, with here and there

* First Journey Through Persia, 1812, p. 104.

veins of red and sometimes of blue." Curzon, however, writing in 1892,* describes the tomb of Hafiz as having once had a lid of marble, but which was carried away by Kerwin Khan and built into the tank in Jehan Nemaq, replacing it by the present sarcophagus made of yellow Yezd marble. Morier further says that the Haft-ten, a Persian pleasure house erected by Kerwin Kahn at Shiraz, is wainscoted with the Tabriz marble, one of the largest slabs being 9 feet long and 5 feet wide, such wainscotings being often inlaid with gold. The college called *Medresse Shah Sultan Hassein*, at Ispahan, also contains some of the same material.

Many Italian churches, ancient and modern, contain numberless illustrations of the extensive use of these materials, and which, in many cases, have been taken for their present use from the ruins of still more ancient structures. The Cathedral of S. Paolo le Mura, at Rome (rebuilt in 1853), contains two beautiful columns of the Egyptian "alabaster" near the entrance, and four others in the canopy of the high altar. These were presented, it is stated,† by the present viceroy of Egypt, and hence came, without doubt, from the valley of the Nile.

The use of the onyx in thin slabs for window panes in cathedrals has often been reported in Mexico as well as in Europe. I am informed by Dr. G. Brown Goode that a portion of the windows in the Cathedral of Orvieto (Italy) are of a yellow-brown banded stone, which is doubtless a lime carbonate from cave or spring deposits in Italy, Algeria, or Egypt. The Church of San Miniato, in Florence, has likewise five windows of similar material. The adaptability of the Mexican onyx for certain forms of interior decoration is well shown in the columns and arch about the entrance of the ark containing the manuscripts of the pentateuch in the new Jewish Synagogue on Fifth avenue, New York City.

In modern times the Algerian onyx has been largely used by the French for interior decoration, as in the grand staircase of the Parisian opera house, and in the manufacture of tops for small stands, turned columns, tables, lampstands, clocks, and similar articles for household use and adornment. The same may be said regarding those of Mexico and the United States. The native Mexicans utilize small pieces in the manufacture of paper weights and knives, penholders, inkstands, card receivers, and plaques, which are sold to tourists. In the United States the material has been utilized, in addition, in the construction of mantels and fireplaces, some of which are very elaborate. In some of our modern hotels there is a lavish display, but in only too many cases, as in the Auditorium at Chicago, most astonishingly poor taste has been shown. The walls are simply sheathed with slabs, apparently without any attempt at selection as to quality, color, or veination, but one laid on

* Persia and the Persian Question.

† Baedeker, Guide to Rome.

after another as carelessly as bricks in a wall. One-half of the amount of material might have been more effective had proper taste been exercised. It is worthy of remark that our architects, decorators, and artisans of to-day seem to rely for effect wholly upon perfection of surface and color, beauty of design and excellence of execution being almost wholly overlooked. Everywhere are flat surfaces, moldings, and machine-made columns, all brilliantly polished, but nothing more. Yet the stone will cut to as sharp an edge as the finest Carrara marble, and is eminently adapted for bas-relief, small statues, busts, and objects of like nature. Its translucency and ever varying shades of color, so far from being defects, are, under proper treatment, actual merits, and it seems almost unaccountable that they have so long been overlooked. Modern manufacturers are not infrequently guilty of the utterly reprehensible custom of seeking to improve the paler hues by paint or other coloring materials applied to the back or unexposed side of the thin slabs, the translucency of the stone being just sufficient to transmit the colors, without permitting its cause to be discovered. This is especially the case with much of the Parisian work now brought into America, but unfortunately the practice is not confined to the French.

CHEMICAL AND PHYSICAL PROPERTIES.

As has been noted, the onyx marbles consist essentially of carbonate of lime crystallized in the form of calcite; very rarely as aragonite. The results of quantitative chemical analyses of some of the principal varieties are given in the accompanying table. As will be noted, the percentage of lime carbonate rarely falls below 90. Next to the lime, iron as carbonate or oxide forms the most prominent constituent, and is apparently the main cause of color variation, the tints depending upon its state of combination, whether as carbonate or sesquioxide. The small amounts of manganese may have some effect, but this could not be ascertained with any degree of certainty. It is interesting to note that the almost milk-white varieties from San Luis Obispo, California (25571), and Lower California (68246) carry, respectively, 3.93 and 2.79 per cent. of iron, calculated as carbonate (FeCO_3). The most pronounced green and brown varieties carry but from 4.19 to 5.51 per cent. of the carbonate, while the faintly tinted greens from Lower California run as high as 7.49 per cent. As a rule, it seems safe to say that the green and red-brown colors are due to this ferruginous constituent, the green colors containing the iron as a carbonate, and the ocher red, yellow, and browns being derived, therefore, by a process of oxidation, as noted on p. 548. Certain amber browns and yellows, (and in one case a bright flesh-pink color), as exemplified in the stones from Suisin City and Sulphur Creek, California, and in all the stalagmitic marbles, both American and Egyptian, are, however, due to organic matter, all burning white, giving off the characteristic empyreumatic odor, and showing but the merest traces, if any, of metallic oxides. It may further be said

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SLAB OF GREEN ONYX MARBLE WITH VEINS OF OCHREOUS BROWN.

Cat. No. 67549, U. S. N. M. Mayers Station, Arizona.

This specimen and those shown in plates 6 and 7 were cut from the same block, to show various stages of oxidation.

U of M



SLAB FROM SAME BLOCK AS SHOWN ON PLATE 5, BUT SHOWING A MORE ADVANCED STAGE OF OXIDATION.

Cat. No. 67549, U. S. N. M.

The percolating solutions permeated along the line extending from the upper left side diagonally downwards toward the right side.

U. S. N. M.

1970



SLAB FROM SAME BLOCK AS SHOWN IN PLATES 5 AND 6.

Cat. No. 67549, U. S. N. M.

The polished face was toward the surface shown in plate 6 and separated by a thickness of not more than two inches.

Characteristics of onyx

	Cry	SiO ₂	H ₂ O.	Total.	Analyst.
	Finely col	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
			0.47	100.29	R. L. Packard.
pe off water....	Granular				
	Microgran		0.29	100.18	Do.
	Microcolu		0.57	99.80	Do.
	Microgran	0.05	(*)	100.04	W. D. Bigelow.
			0.40	99.41	G. P. Merrill.
naly.....	do	0.05	(*)	100.19	W. D. Bigelow.
r.....	do	0.04	(*)	99.78	Do.
to odor.....	Granular		0.37	99.75	R. L. Packard.
ht odor.....	Finely col				
	Microcolu			99.35	Do.
faint odor....	Microcolu				
	Finely col				
	Microcolu		0.38	99.93	Do.
	do		0.68	100.29	Do.
	do	0.06	(*)	100.56	W. D. Bigelow.
	do			99.20	Do.
yields little	do				G. P. Merrill.
				100.00	Dr. Edw. Hitchcock.
no appreci-	Finely col			99.93	R. L. Packard.

as follows: Green variety.

UN

that the most constant distinction between those of the onyx marbles which are spring deposits and those which are formed in caves is the absence, in the latter, of appreciable quantities of metallic oxides. This is presumably to be accounted for on the supposition that the cave marbles result from the solvent action of cold carbonated water on limestone containing, aside from the iron oxides, only mechanically included impurities which do not enter at all into solution, but remain in the form of the ochreous residual clays which are so characteristic of limestone caverns the world over. The travertines, on the other hand, result from the solvent action of heated solutions on deep-seated siliceous rock, and which as a result carry not merely lime, but a considerable proportion of rarer constituents as well. That these rarer constituents are not more abundant in the deposits themselves is due to their unequal solubility and the consequent fractional separation which takes place on evaporation. This separation has already been alluded to, on p. 549. The reverse of the above-stated rule does not always hold good, since, as above noted, the Suisin City deposit, which is a travertine, contains scarcely a trace of iron. The percentage of manganese, as will be noticed, is, with but two exceptions less than one-half of one per cent. These exceptions are (1) a faintly greenish stone from Lower California, and (2) a pure milk white variety from Lake Oroomiah, the latter yielding 4.34 per cent. of this material calculated as a carbonate, ($MnCO_3$) or 2.68 per cent. when calculated as oxide (MnO). The magnesium carbonate is almost invariably present in small amounts, and singularly enough is highest in the cold-water (cave) deposit from Syout, Egypt (61336), where it reaches 6.88 per cent. Careful tests were made for the rarer elements, but with negative results in the most cases, the Suisin City stone showing 1.59 per cent. of strontium carbonate; that from the Hacienda del Carmen, Mexico (61337), 1.34 per cent. of calcium sulphate, and that from San Luis Obispo 0.25 per cent. of tricalcic phosphate, $Ca_3(PO_4)_2$. The milk white stone from Lake Oroomiah yielded 2.30 per cent. of calcium sulphate and 0.24 per cent. of tricalcic phosphate.

In order to illustrate the possible changes in color from secondary oxidation, pls. 5, 6, and 7, are given. The slabs were all sawn from the same block, not above 10 inches in thickness, and which was at first supposed to be nearly uniform throughout. In pl. 5, it will be observed, there is a wide vein of ochreous brown extending somewhat diagonally from top to bottom, with smaller veins cutting it from left to right. In the second slab the vein has extended so as to include the whole upper left section, while in the third the original green has been almost wholly obliterated. It is easy to perceive that this change in color has been brought about wholly through the oxidizing influence of percolating solutions which followed the lines of existing flaws. In no case that has thus far come under my observation am I inclined to regard these veins and dashes of red and brown as original, but as results of secondary oxidation.

An intermediate stage in the process is shown in the small block figured on pl. 8, where oxidation has gone on from all sides until only a nucleal mass of green remains, into which the oxidizing process was extending along the lines of deposition, much as the process of serpentinization extends along the curvilinear cracks of an olivine granule.

Two independent analyses of the green and oxidized portions from this specimen (67825) yielded in the one case 5.51 per cent. of iron carbonate (FeCO_3) for the green variety, and 4.06 per cent. of the carbonate, and 1.73 per cent. of sesquioxide (Fe_2O_3) for the brown. In the second case 4.27 per cent. of FeCO_3 in the green variety, and but 1.22 per cent. of the same salt in the brown, with 3.53 per cent. of the sesquioxide. In both cases the total amount of iron calculated as Fe seems a trifle the largest in the oxidized portion (2.65 per cent. in the green as against 3.06 per cent. in the brown).

The completed stage of oxidation is shown in pl. 15. The original green color is wholly effaced, and the block, when cut across the grain, gives a unique combination of red-brown colors which, together with the original lines of deposition, give an appearance so like that of certain tapestries that I have given it the name of *tapestry onyx*.

In a few instances the shades of color are produced by mechanically included impurities, as in pl. 12, from a specimen from San Luis Obispo, California. Visitors to the California pavilion in the mines building during the Exposition at Chicago in 1893 will recall the beautiful and unique pictures in stone there shown. This coloring matter, in its various shades of smoky brown, is due to inclusions of clay parallel to the plane of deposition. It would appear that during the time the stone was being deposited the waters became temporarily charged with silt, which settled in thin films over the uneven, often botryoidal surfaces already formed, to become entombed in the mass of the stone when the onyx-forming stage was resumed.

In structure the onyx marbles are invariably holocrystalline, sometimes granular, but much more commonly with a fibrous or radiating columnar structure, the fibers or columns being composed of calcite crystals elongated in the direction of their principal axes and standing at approximately right angles to the plane of deposition, as noted by Sorby* in deposits of similar origin.

Twin forms so characteristic of the calcite of metamorphosed sedimentary deposit, or even the secondary calcite in veins and cavities of eruptive rocks, are quite lacking. Mechanical inclosures of any kind are almost wholly wanting, as may be inferred from the analyses. The banded aragonite from New Mexico (60631) shows the dark color to be due to included particles of a coal-black color, which give reactions for manganese oxide.

The characteristic banding or "grain" of the stone is due to lines of accretion comparable with the lines of growth upon the trunk of a tree

* Quarterly Journal of the Geological Society of London, Vol. xxxv, 1879, p. 1.





FIG. 1. OF GREEN ONYX MARBLE WITH EXTERIOR ZONE OF RED BROWN OXIDIZED MATERIAL.
Cat. No. 67225, U. S. N. M. Mayers Station, Arizona.

100

each layer representing successive surfaces over and upon which the lime-holding solutions have deposited new materials. In some instances the successive layers vary more or less in character of crystallization and color, due to a slight change in contents of organic matter or metallic oxides, or physical conditions, whereby the material is rendered more or less opaque. The characteristic feature which above all others adds beauty to the stone is its translucency, which is a purely physical quality. As a rule the crystallization, in sound blocks, continues uninterruptedly upward through the successive layers for a distance of several millimeters, so that there is no tendency toward separation along these layers until a point is reached where, owing to impurities in the water, or it may be a temporary cessation of deposition, crystallization ceased. On beginning once more, such lines not infrequently form lines of weakness. A not uncommon structure is that shown in fig. 1 of pl. 9. Crystallization starts from a series of points on a preexisting surface and progresses upward and outward forming a series of inverted cones. This structure is evident only on close inspection and in slabs sufficiently thin to be translucent.

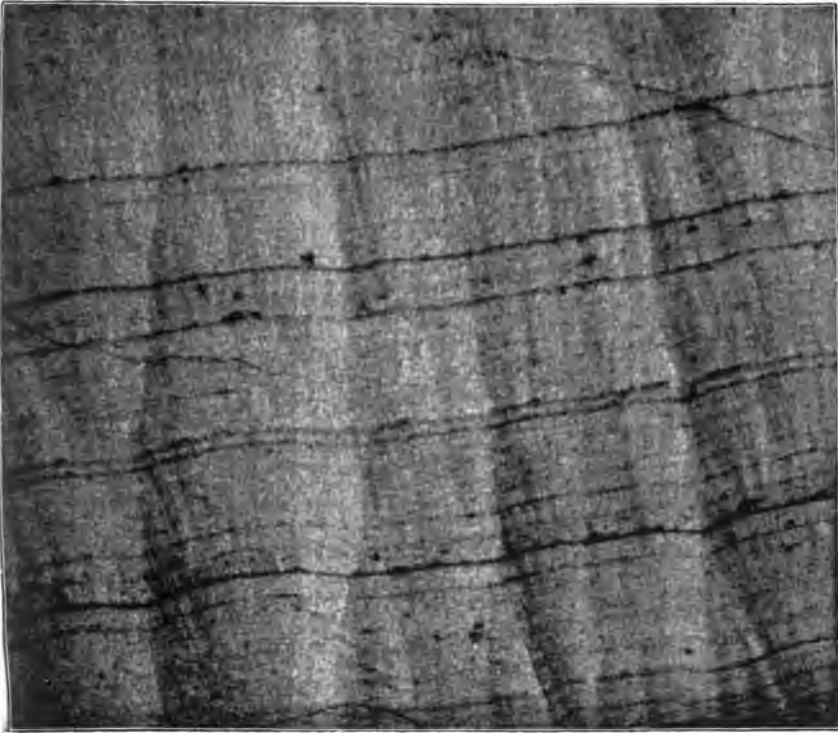
As a natural consequence of its mode of deposition the surface structure is usually botryoidal. Cut across the plane of deposition the structure is then as shown in fig. 1 of pl. 1. Cut at right angles to this, the structure, owing to the wavy, botryoidal nature of the original surfaces, is often wonderfully beautiful and always interesting. The colors continually appear and reappear in varying degrees of intensity accordingly as they lie upon the immediate surface or are subdued by intervening layers of colorless material. One sees in fact not merely the colors which lie upon the surface, but those beneath as well, subdued, enhanced, enriched it may be, by those which overlie or lie beneath. It is in this characteristic that lies the chief claim for beauty, and its entire separation from marbles of the common, sedimentary type. The figures given on the pls. 14, 17 and 18 will serve to show, so far as is possible by photograph, the varying structure described.

The cave marbles are as a rule much less translucent than the travertines, coarser in crystallization, and hence more liable to fracture. They are, moreover, less homogeneous, containing many cavities and interspaces which have never been filled. In the columnar forms a pronounced zonal structure is common, as shown in the cross and longitudinal sections in figs. 3 and 4 on pl. 13. In the more massive forms we find the bandings as in the travertines, but without the delicate crystallization.

LOCALITIES: DOMESTIC AND FOREIGN.

Arizona.—Several deposits of onyx have within a few years been located in Arizona, though so far as at present known to the writer, but two are of such extent as to be of any commercial value. These two are both in Yavapai County, and possess many characters in common.

The first to be described lies at Mayers Station, on the stage road leading from Prescott to Phoenix, and some 28 miles southeast of the first-named town, which at time of writing, is the nearest accessible point by rail. What stone has thus far been shipped is hauled by wagon to Prescott, and by the Prescott and Arizona Central Railroad 70 miles north to the Atlantic and Pacific Railroad, which affords an outlet both east and west, as occasion demands. At time of writing there is, however, in process of construction a new line connecting the Santa Fe system on the north with the Southern Pacific, and which will pass sufficiently near the deposits to greatly diminish the hauling distance, as well as afford the benefit of competing freight rates furnished by the two lines. The deposits occur on the western side of what for a considerable portion of the year is a dry ravine, but which in the winter and rainy season carries a variable and often turbulent body of water, and rejoices in the name of Big Bug Creek. The country rock is highly metamorphic schist standing nearly on edge with occasional dikes of basic eruptives. The onyx proper occurs interbedded with a coarse breccia formed of schistose and dioritic fragments embedded in a sandy and calcareous matrix, the entire formation occupying a low range of hills, of which an area of 200 acres is estimated by the company to comprise all the quarryable material. Standing at the stage station and looking westward across the creek, one sees the low bluffs of onyx where the edges of the bed have been exposed in the work of exploitation. At first glance the outlook is not inspiring. The rock weathers gray and rusty brown, breaks down under the prolonged exposure to which it has been subjected, and appears like anything but the beautiful stone it really is. Closer inspection is, however, more assuring. At the shallow openings that had been made in the bluffs and on the top of the hill, at the time of the writer's visit (1891), the onyx occurred in irregular somewhat concentric layers, (pl. 2), from the fraction of an inch to 2 or more feet in thickness, and which are traversed parallel with the plane of deposition by wavy bands of color in all shades of amber, white, ochre yellow, brown, deep ochreous red, and green of a most beautiful emerald shade. The sound layers of stone are separated from one another by porous cellular layers, so that slabs of large size can be obtained only by cutting parallel with the banding, *i. e.*, with the plane of deposition. This in itself is no drawback, since the colors blend much better and the general effect is vastly richer than when cut across the grain. No two of the openings show material of exactly the same nature as to color and markings, or as to size and thickness of the blocks. In all, the stone lies in layers readily separable from one another, and which, as a rule, thicken and thin out irregularly. The more highly colored varieties carry, as shown by analysis, nearly 5 per cent. of carbonate of iron. Through the oxidizing effect of percolating solutions this carbonate has in many instances been converted into a more or less hydrated oxide whereby the green is changed to red, brown, or amber-yellow colors in



1



2

Fig. 1. Microscopic structure of onyx marble showing fibrous structure extending upward across the plane of deposition.
Fig. 2. Vase of "Egyptian Alabaster" (stalagmitic marble), from Sakkarati. From the Abbott collection of Egyptian antiquities in the possession of the New York Historical Society.

all shades. This oxidation has naturally followed along the lines of jointing and penetrated the more porous layers, so that what were once large blocks of homogeneous green are now surrounded by a crust of varying thickness of the oxidation product. All stages of the process are seen at the various openings, from those in which the green stone is covered with a mere crust, and scarcely sufficiently veined to give a desired variety, to those in which scarcely a trace of the original green remains, but the whole block is of a red-brown color in varying shades. At times the oxidation has been accompanied with a removal of so large a proportion of the lime carbonate that the texture is destroyed; the stone becomes somewhat cellular or spongy, and does not acquire a good surface and polish. In other cases, the stone still retains its compact structure and susceptibility to a high polish, though necessarily it loses its translucency and becomes quite opaque. Nevertheless, the stone is by no means undesirable for either furniture toppings or for decorative purposes. The colors are rich but not gaudy, and, when properly prepared, are capable of effects both unique and beautiful. There is in the National Museum a slab of the oxidized stone (60845) of brown and red color so cut with the grain as to resemble in a wonderful degree a piece of antique tapestry. (pl. 15.) The details of its structure are intricate in the extreme, and since what is to be seen by a careful study of them depends almost wholly on the vividness of one's imagination, the writer drops the subject to be taken up, it may be, by those more gifted, either in imagination or in the faculty of expression. This type of onyx, I may say, differs from anything I have seen elsewhere, and, while the present workers regard it as valueless, and it is doubtful if the quarries can be relied upon to produce any large supply, or even two blocks alike, I still regard it as a beautiful stone, and one well worthy of consideration. In certain of the outcrops no green at all appears, but the stone lies in somewhat wavy layers of from 1 or 2 to 12 or 15 inches in thickness, and which are traversed by narrow alternating bands of brown, white, yellow, and sometimes pink. This variety of onyx is more granular in structure—due to coarse crystallization—than the green onyx, less translucent, and, on the whole, much less desirable. It is, nevertheless, a fine marble. Owing to the wavy nature of the bands, they appear and disappear in the form of veins, blotches, streaks, and clouds of varying intensity in color when the stone is sawn into slabs. The compact, highly lustrous green stone, with a surface almost as close as enamel, and with its veins and dashes of red and brown, is, however, the most desirable of all.

The so-called Cave Creek quarries of Arizona are also in Yavapai County, but in the extreme southern part, near the Mariposa County line. At present they are accessible only from Phoenix, and over a road the latter 12 to 20 miles of which is hilly in the extreme. In riding over it one can but be reminded of a saying in reference to the Territory to the effect that "if Arizona 'd been laid flat it would be bigger'n any two States in the Union." But to reach the market the

quarried stone must be dragged on wagons over this 50 miles of roadway to Phoenix, and thence shipped by rail. With this great drawback, coupled with high freight imposed by a railroad free from competition, the quarries labor under great disadvantage.

The country rock here is a slaty schist injected with quartz porphyries and diorites, all sporadically overlaid by basalt, the diorite cropping out in the rounded foothills, and weathering reddish. The main onyx ledge lies on the western slope of a low basalt-capped hill. The lowest underlying rock, as exposed in the creek bed a few rods below the quarry, is also basalt, but of a coarse texture and gray color. In the quarry opening the lowest rock exposed is a calcareous breccia, formed of fragments of slate and pebbles of basic eruptive rocks cemented by a friable travertine. At the time of the writer's visit (August, 1892) the outcrop, as exposed by digging, was some 200 yards in length and presented some remarkable features. The maximum thickness of the bed was about 10 feet. As exposed, it was not, however, continuous, but evidently had been thrown out of place and more or less shattered and broken by the extrusion of the basalt, the face of the quarry having the appearance shown in pl. 10.

The prevailing colors here, as at Mayers Station, are green and yellowish, with veins of ochereous brown and red. The tints are beautiful in the extreme, and the best quality of the stone is certainly very fine. Clear uniformly green stone is not to be had in blocks of any size, but all are filled with reticulating veins. There is a large amount of waste material in the stone thus far removed, owing to the oxidation which has gone on in the same manner as at Big Bug Creek. There are also occasional small masses of chalcedonic quartz. The deposit is unique, in that the largest blocks thus far obtained have their greatest dimensions at right angles with the plane of deposition. Slabs 4 feet wide could thus be cut across the grain, and while by this method the beautiful blending of the colors is lost, still the wood-like grain, or onyx-like banding, is thus brought out, and is greatly preferred by some. At date of writing nearly all the material thus far quarried has been literally dug out of the tufaceous material, in the form of corroded, irregular blocks of all shapes, and in sizes including at most but a few cubic feet. What the large bed will yield, and how far it extends into the hill, is yet to be ascertained. (See pl 11.)

California.—Within the State limits of California are several deposits of onyx marble, which may, with the increasing wealth of the country, become important sources of supply. At present but one is actively worked, difficulty of access and cost of transportation, together with a limited market on the Pacific Coast, operating against an extensive development. The most noted of these deposits, and indeed the only one that has yet proven of any commercial importance, is located near the town of Musick, San Luis Obispo County, in the heart of the Santa Lucia Mountains. According to the report of the State mineralogist*

*Tenth Ann. Rep. State Mineralogist of California, 1890, p. 584-85.



QUARRY OPENING AT CAVE CREEK, ARIZONA, SHOWING THICKNESS OF DEPOSIT.

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CUT IN HILLSIDE AT CAVE CREEK, ARIZONA, SHOWING DETACHED MASSES OF CORRODED ONYX.

U S G E O L O G I C A L S U R V E Y

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there are two openings or outcroppings, some half a mile apart, lying in sections 9 and 16 of township 31 south, range 15 east, Mount Diablo meridian. The inclosing rock is a slaty sandstone, the ledges standing nearly on edge and having a thickness of about 16 feet. The outcroppings lie one on the northern slope of the ridge and the other on the southern, the hill rising about 80 feet between them. Whether the two are parts of the same vein or bed is as yet unknown. The strike of the more northern croppings is directly toward the southern, though that of the southern is diagonal to the course of the others. The stone is very close in texture, acquires a high lustrous polish, and shows when cut across the grain a beautiful wood-like banding. The colors are quite variable, but not so pronounced as those of Arizona. White, translucent, with a pearly luster, is the prevailing type, but pinkish and purple shades, with tinges of blue, orange, red, and olive, are not uncommon, the colors being sometimes in blotches and sometimes in veins. A peculiar translucent, smoky variety is not uncommon, resembling some varieties of true alabaster. A pair of columns prepared some time ago excited considerable admiration from showing two apparent geode-like cavities lined with crystals of burnished gold set in a dark olive and purple ground. In reality no cavities existed, the stone being solid and sound throughout.

One of the most remarkable and unique varieties, but which occurs only sporadically, is of a translucent white, but so injected parallel with the bedding with argillaceous matter as to give most wonderful cloud-like effects, such as words can not satisfactorily describe. Visitors to the California pavilion at the World's Columbian Exposition at Chicago in 1893 will recall the unique pictures in stone there displayed by the Kessler Brothers, of San Francisco. In some slabs the dark coloring matter was so distributed as to give the effects of precipitous mountains, with tops in the clouds and lakes and valleys at their feet. In others the effect was as if the surface were roughly mammillated with smoky clouds of varying degrees of density. In all these forms the slabs must be cut moderately thin and parallel to the bedding and viewed by transmitted light in order to bring out the best effects. (Pl. 12.) The coloring matter in these cases was found to be mechanically included clay, which remained as a muddy sediment in the bottom of the beaker when the stone was dissolved in hydrochloric acid, as already noted.

It is stated in the report above referred to that the stone could be taken out in blocks 10 feet square (thickness not stated) without a flaw. The material is hauled by wagon from the quarries to Musick, and shipped thence by rail to San Francisco, where it is worked up. Active and systematic quarrying was begun here in the summer of 1890.

Several years ago a resinous travertine occurring as superficial deposits on a bare hillside near Suisun City, in Solano County, was worked somewhat spasmodically, but was soon abandoned, owing in part, it is said, to the damage done by injudicious blasting. It is probable,

however, that but little could have been done under the most favorable of circumstances, owing to color and textural qualifications. The stone varies in color from light amber to deep resinous brown, and often shows most beautifully the peculiar wavy, undulatory bands of color so characteristic of rocks of this class. Both color and texture are, however, variable, and it is impossible to obtain slabs of any size that are not rendered undesirable through porous layers, or monotonous and even objectionable from their dull resinous hues. Some beautiful material was here obtained, and doubtless more might yet be found, but Americans, and those who call themselves such, have yet to learn how to conduct such an enterprise profitably. Another small deposit that was worked to some extent exists on Sulphur Creek, in Colusa County. This is a very beautiful stone, of a rich deep-brown color, with bedding veins of lighter yellowish-brown. The quantity is said to be quite limited and to be obtained only in blocks of small size. The coloring matter in both these cases is wholly organic, analyses showing scarcely a trace of metallic oxides or other impurities. In the reports of the State mineralogist the Sulphur Creek stone is described as occurring in the form of a vein consisting of two seams, each about 5 inches thick. A quantity of the rough stone was at one time sent to England, where it found a ready market. Some onyx of a light-brown color, beautifully veined, occurs in the quarries of the Colton Marble Company, in San Bernardino County. It is said to have been used only to a slight extent. The writer never having seen samples, can express no opinion regarding its qualities. Near Crescent Falls, on the Sacramento River, 6 miles below Sisson, in Siskiyou County, is still another deposit, yielding material of a beautiful emerald-green color. I am informed by Mr. J. S. Diller, of the U. S. Geological Survey, that the stone occurs only in the form of a vein 4 to 6 inches wide in granite, the vein being open in the middle and allowing the escape of an excellent spring of soda sulphur water. The deposit is very irregular and of limited extent along the strike, and probably also limited in depth. It is too irregular to furnish large slabs and of too small extent to afford any considerable quantity of material. Onyx marbles have also been reported at Gold Run, in Placer County; Las Penas-qintos Creek, San Diego County; Oro Grande, San Bernardino County; Vacaville, Solano County; Geyserville, Sonoma County; Tuscan Springs, Tehama County; Three Rivers, in Tulare County; near the head waters of Bel River, in Lake County; Bridgeport, Mono County; Little Castaca Cañon, Los Angeles County, and on Santa Catalina Island. None of these have, however, as yet been shown to be of sufficient extent to have any commercial value, nor has the writer seen any of the material.

Eastern Appalachian Region.—The valley of Virginia, extending throughout the entire length of the State, running in a southwesterly direction from Harpers Ferry on the north, is underlaid by limestones of Silurian or Cambrian age. Percolating waters, acting through untold years, have dissolved out, in these, numerous caverns in the manner



SLAB OF SAN LUIS OBISPO ONYX MARBLE, CUT PARALLEL WITH PLANE OF DEPOSITION AND SHOWING CLOUD-LIKE EFFECT
FROM INCLUSIONS OF CLAY.

Cat. No. 61306, U. S. N. M.



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STALAGMITIC MARBLES.

- Fig. 1. Cross-section of block. Cat. No. 67366, U. S. N. M. Marion County, Virginia.
Fig. 2. Cross-section of block. Cat. No. 67617, U. S. N. M. El Paso, Texas.
Fig. 3. Longitudinal section of stalagmite. Cat. No. 67981, U. S. N. M. Luray, Virginia.
Fig. 4. Cross-section of stalagmite. Cat. No. 67981, U. S. N. M. Luray, Virginia.

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already described. The Luray Caves, in Page County, and Weyers Cave, in Augusta County, are among the most widely known of these. There are, however, hundreds of smaller and less interesting ones, which may have become wholly or partially refilled by stalactitic and stalagmitic matter. Very many instances present themselves in which portions of the roofs or sides of these caves have been removed by erosion, leaving the white, creamy, or amber yellow stalagmitic material exposed on the surface, where it shows up in strong contrast with the dull gray limestone which forms the prevailing country rock. It has not infrequently happened that these deposits are of sufficient extent to warrant the opening of small quarries, though the stone is rarely of sufficient beauty to enter into active competition with the onyx marbles of Mexico, Arizona, California, or Algeria, with which they are chemically almost identical. Nevertheless fine blocks are frequently obtainable, showing a pronounced banded structure when cut across the plane of deposition (pl. 13), and it is rather to be regretted that no more successful attempts have been made toward keeping them upon the market. Such attempts as have been made have almost uniformly failed, partly owing to a lack of definite knowledge as to the character of the deposits on the part of those in control, and partly from the fact that the work was undertaken on too extensive a scale. The average American has yet to learn that a small business, carefully conducted, may be a surer source of income than many of the gigantic schemes which flood the country to-day. The managers of the caverns above alluded to might add materially to their incomes, as well as to the satisfaction of their visitors, by exposing for sale small objects made from such blocks of stalactite or stalagmite as could be spared without defacement of the cave. So far as the writer is aware it is only at Mammoth Cave, in Kentucky, that any attempt is made in this line, and here one finds only a few small charms and paper weights manufactured at odd moments by the natives. Near Harrisonburg, in Owen County, are considerable deposits of stalagmitic material which have yielded small pieces of great beauty. An attempt was made not long ago to work the quarries, but with little success. The marble dealers, knowing they could not be relied upon as constant sources of material, ignored them utterly, and it will not be until our wealthier classes learn to more fully appreciate home products that we may hope to see these marbles receive the attention they deserve.* Nevertheless it is not

* It must be acknowledged, however, that the difficulty lies not wholly with the wealthier classes, who can scarcely be expected to admire or demand any article concerning the existence of which they are ignorant. Americans abroad pay fancy prices for small articles of ornament and art simply for the reason that these are everywhere exposed for sale, and the attention is at once attracted. Let but the American exert equal taste and patience in working up our native materials, and it is possible we might be able to tell quite another story. Brazilian agates, colored and polished in Germany, are sold to the tourists of Colorado and other Western resorts as local products, and I have seen the so-called "tiger-eye" (Crocidolite) from South Africa sold by dealers in Montana to the unsuspecting tourist as fossil wood from Arizona.

uncommon to find mantels and chimney pieces of the stone in the houses of people living in the vicinity. Such, as a rule, are the work of local stone dealers, and cut from blocks found loose in the fields. Fine blocks of stone from caves that have been almost completely refilled have been found near Lexington, in Rockbridge County, a slab some 18 inches square of which is among the collections of the National Museum. In one of the extreme southwestern counties deposits of this nature were worked some thirty years ago by a local stone-cutter, but who, it needs scarcely be said, was a foreigner. The material, singularly enough, was utilized mainly for tombstones. As a result the churchyards of the region present an appearance quite unique, and wholly unlike anything I ever saw elsewhere. In place of the white marbles, gray granite, or dull slate of the ordinary churchyard, we find here rows of white, amber, and resinous stalagmitic marbles, some of which are translucent and still beautiful in spite of their years of exposure, though naturally roughened and in some cases badly flawed and seamed.

Quarries in the broken-down caves of eastern Tennessee, southwestern Missouri, and Arkansas have also been opened and worked for a limited period, some of them furnishing a fair grade of material, but for which there proved only a limited market. The attempt is invariably made to utilize the product mainly for furniture tops and wainscotings, in which line it must be brought into competition with the more desirable travertines and high-grade decorative colored marbles, as those of Siena and Algeria. For small ornaments, vases, columns, and certain forms of bas-relief the material is best adapted, and it is of little use to seek a market elsewhere.

Colorado, Utah, and New Mexico.—Deposits in every way similar to those noted above have been reported from Colorado, and, indeed, are likely to occur in any limestone country. Dark and light amber varieties were exhibited as from Pelican Point, Utah County, in the Utah exhibit at the World's Columbian Exposition in 1893. A much more striking variety was in the form of bright lemon and orange, dark buff, and chrome yellow and white slabs from deposits near Lehi, in the same Territory. The stone was beautifully translucent and the colors of astonishing depth and brilliancy—so much so that it at first seemed scarcely possible that they could be natural. The writer was informed by Mr. F. T. Mills that the material occurs in the form of a vein some 4 feet in width in limestone. Near Rio Puerco Station of the Atlantic and Pacific Railroad, in Valencia County, New Mexico, are deposits of travertine, or stalagmitic matter, which have been exploited thus far only in a preliminary way. The stone varies from whitish to deep smoky, almost black, and from translucent to opaque. The better varieties show on a polished surface a silky luster and a radiating fibrous structure. It is distinctly banded parallel with the plane of deposition, the bands varying from faintly whitish to nearly black, the dark bands being mere lines of inclosures. The stone, while lacking

in richness of color, is, owing to its luster and fibrous structure, very attractive. The specific gravity is 2.88; before the blowpipe it turns white and crumbles away, agreeing in these as well as its fibrous structure with the properties of aragonite.

Mexico.—To the average American the name onyx is inseparable from that of Mexico, since from this source has, until within a few years, been brought the almost entire commercial supply, though small quantities are imported from Algeria and Egypt.

There are many small, sporadic occurrences of onyx throughout the volcanic areas south of the city of Mexico, and doubtless in other parts of the republic as well, but which are as yet unknown or unworked owing to lack of facilities for transportation. Until quite recently the principal source has been the region southeast of Puebla, between Tecali, Tzicatlacoya, and Tepene. Recently deposits have been found near San Antonio.* The underlying rock, so far as I am able to glean, is in most cases a Cretaceous limestone, though frequently associated with recent lavas. Those deposits now worked are naturally along or near the lines of railway leading to Vera Cruz and the city of Mexico.

The stone of these localities has been worked from a very early period of American history, perhaps even before the advent of the Spaniards and the blotting out of Aztec civilization. The best modern account of the quarries, if such they can be called, that I am able to find is that given by an unknown writer in the *Engineering and Mining Journal* for December 26, 1891. On this I have drawn very largely in the descriptions given below, although I cannot vouch for its accuracy.

Among the Aztecs the stone was so highly prized for its beauties that it was deemed too sacred to be given to the ordinary uses of common mortality, and was devoted almost solely to the ornamentation of religious edifices or the manufacture of sacrificial vessels. So strict and arbitrary was this limitation on its use that its Indian name, "tecali," is merely a corruption of the Aztec word "teocall" (Lord's mansion), a name given by the Indians to their temples.† With Cortez and his freebooting followers the stone found as high favor, while with that peculiarity that always distinguished them of picking out the best under all circumstances, the padres regarded it as a most meet and proper offering to the church from the devout. Altars and baptismal fonts were always made of it when it could be obtained, and among the most

* *Beiträge zur Geologie und Paleontologie der Republik Mexico.* Von Drs. Felix und Lenk, III. Theil., p. 129.

† Teocaltzinco, Teocal-tzinco, Teocalcino. Un templo sobre medio cuerpo humano, signos, uno figurativo de *teo calli* (casa de Dios) y el otro fonético, terminal y diminutivo, *tzinto*, significan; "en el lugar del pequeño templo" ó en pequeño Teocaltepec. Catalogo Alfabético de los Nombres de Lugar Pertencientes al Idioma "Nahuatl" Estudio Jeroglífico de la Matricula de los Tributos, etc., por el Dr. Antonio Peñafiel. 1886.

From this it would appear that the derivation of the word as given in my "*Stones for Building and Decoration*" (Wiley & Sons, New York) is erroneous.

notable sights connected with a tour of Mexico are the magnificent collections of articles of this marble which are to be found in many churches, particularly that in the cathedrals of the cities of Mexico and Puebla, and in the churches of Leon, Queretaro, and Guadalajara, several of which contain perfect slabs 3 and 4 feet square, an extraordinary size on account of the small and irregular shape in which the stone is found.

During recent years fashion has taken up what the priests of these two religions thus marked with their approval, and the stone under the name of Mexican onyx, with its capricious markings, has become so well known as to make a detailed description of its different varieties unnecessary. To those who have made its acquaintance, though only through the medium of the ordinary onyx table top, clock, or the interior ornamentations of public buildings, beautiful as such are, it would be hard to convey a correct idea of the exquisite beauties of the finer grades of the marble. While the ordinary grades commonly encountered probably surpass in elegance any similar material, it is only in the light and dark green, the ivory-colored, the brilliantly banded, and the dark-red varieties that a full realization of the stone at its best is had.

In the quarries the stone is found in the form of detached masses, ranging in size from a few inches up to 10 or 12 cubic feet. Larger sizes are occasionally found, but so rarely that the event is a notable one, while the value per cubic foot is correspondingly increased. For example, the value of a piece containing 1 or 2 cubic feet would be estimated to be ordinarily \$3 per cubic foot in Mexican money, but were the piece to contain 25 or 30 cubic feet, the valuation would be about \$15 per cubic foot. This is for ordinary stock; with green and the other finer grades it would be very difficult to form any estimate whatever. This smallness of available sizes is one of the principal defects of the stone, and one with which the best skill has battled in vain. With its other defects, that of occasional flaws or holes, ranging from a tenth of an inch to 2 or 3 inches in diameter, more success has been had in remedying the negligence of nature by filling the smaller with a cement mixed with powdered portions of the stone, while in the larger a piece of the onyx is very often boldly inlaid with such skill as to defy detection on a cursory inspection. With the growing inability to supply the demand for onyx, this last method of making the most out of what remains of the stone has been pursued to a great extent, and with very good success except where the article so "improved" is subjected to sudden changes of temperature, in which case the effect of our northern climate at once becomes apparent, and the best of work under the irregular processes of expansion and contraction soon becomes unsightly. Almost as common but a more questionable method of "improving" the stone is that of sawing the inferior qualities that lack color into very thin slabs, so thin as to be almost translucent. These are then operated on by an "artist," who adorns



ONYX MARBLE CUT PARALLEL WITH PLANE OF DEPOSITION
Cat. No. 26011, U. S. N. M. Pueblo, Mexico.
Colors, green and red.

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one side with a variety of colors and pencilings that make a very fair counterfeit of the real first-class article, after which the side that is painted is covered with a coating of very fine cement, which gives it the appearance of having been merely sawed and left unpolished. This class of work is often done so well that when first finished it will deceive any but the sharpest of experts, but under a year or two of use, the swindle becomes apparent, and soon nothing remains but a thin, transparent slab of stone.

The formation in which the marble or onyx is found is a tough, reddish or dark-brown clay, overlying a closely cemented conglomerate. This is the usual form, but in one instance—that of the Antigua Salines, on the Rancho del Carmen—it is found in a hard, flint-like country rock which appears to be more of a bastard jasper than anything else. In this instance the onyx appears as a regular vein formation, the veins varying from 1 to 12 inches in width.

Of the quarries themselves all are small. The most famous—*La Pedrara*, in the district of Tecali, 21 miles from the city of Puebla—does not cover more than 3 acres, while the average depth of the quarrying is not over 7 feet. The value of the onyx taken from this small area, though, is hard to realize. The high reputation of the stone is recognized the world over, but it is very doubtful if one-tenth of what has been sold as “*La Pedrara*” during the last quarter of a century ever came from it. At present no attempt is made to work the quarry, in fact no indication of onyx in the place is to be seen; the only effort made in obtaining onyx from it being by sorting over the old dumps or refuse places which have accumulated during its active existence. From these is taken every piece of onyx that will square 6 inches or over. The process is slow, while the yield is seemingly very small in return for the labor. The onyx obtained is of a very fine quality of green, ranging from a very light to a very dark tint, and, as a rule, showing a slight dash of red or pink. Occasional pieces of variegated colors are found which are very fine, while the texture is very good.

Next in importance to *La Pedrara* is *Antigua Salines*, in the district of Tehaucan, and which has already been briefly mentioned on account of its peculiar geological formation. The quarry covers over an area not exceeding two acres, and forms the face of a hill about 250 feet high. In working it, the system has been simply a process of gouging out the onyx and the rock which encases it, until into the side of the hill there has been excavated a hole 100 feet in width by 50 feet in height and 60 feet deep, looking very much as if an immense shovelful had been taken out. The onyx is variegated in colors, and is ranked next to *La Pedrara*.

Ranking third, probably, in importance is *La Sopresa*, which covers an area of about 5 acres, and is located about 35 miles west of Antigua Salines, in the same district. The onyx from this quarry is semitranslucent, white, totally devoid of colors, save where an occasional mass

of green is found. The quarry has been worked for the last fifteen years only, and is at present the largest producer of onyx in Mexico. Sizes ranging as large as from 2 to 3 feet square can be obtained, which is something extraordinary in Mexican onyx deposits, and the supply in "sight" seems to be sufficient for several years. The total absence of any color to set off the pure white is to be regretted, but as it is, the demand for the stone is sufficient to tax the quarry to its utmost to supply it.

Directly east from Sopresa, about 4 miles, is found the quarry of *La Mesa*, lying, as its name indicates, on a level table-topped mountain. The quarry shows quite extensive working, the product being a variegated onyx, which, however, lacks the brilliancy shown in the stone of Antigua Salines. It covers an area of nearly 30 acres, being the largest quarry in Mexico. Occasionally quite large pieces are obtained, but the average sizes prepared for shipment will not exceed 15 by 10 by 6 inches, while pieces as small as 10 by 6 by 10 inches are also shipped, both to Europe and America. This, however, is the case with all the quarries, and it is the exception when pieces larger than the first mentioned are exported.

In addition to the quarries here mentioned there are many others of less importance, either by reason of their small output or from having been worked out. Among these the most interesting, on account of historical associations or past records, are those known as El Mogote, Lajas, Agua Esconda, Desamparo, Mehauntepec, Tepeyac, Tecoloco, La Paoma, and La Reforma.

Baja California.—The last, and perhaps most important of the American deposits to be described are also on Mexican territory, but on the peninsula of Lower or Baja California, near the Gulf Coast, and some 150 miles south from San Diego. One of these, that at the Tule Arroyo, has been already sufficiently described on p. 547. The second deposit, or rather series of deposits, lies in the open desert some 3 to 5 miles to the southwest of the arroyo. The region is one of low rolling hills and flat-topped mesas, with shallow valleys and dry water courses. The prevailing rock, a friable sandstone, with alternating layers of calcareous conglomerate and onyx in isolated patches. The surface is everywhere covered with irregularly rounded and angular fragments of eruptive rocks from the hills in the near vicinity.* Aside from the onyx and the characteristic lake bed deposits all traces of spring and lake action have long since disappeared, and the region is an arid waste with only cacti, "sirios" (*Fouquieria splendens*) and the *agave shawi* in the immediate vicinity, with the *mesquite*, *paolo verdes*, stout, low-branching elephant wood (*veatchi Cedrocensis*) and pole-like *fouquieria columnaris*, or giant cactus (*cereus pringlei* (?)) like clustered mill logs along the dry water courses or extending for dreary miles along the flat-topped

*For a detailed account of the geology of the peninsula, see "Geological Sketch of Lower California," by S. F. Emmons and G. P. Merrill, published in Bulletin Geological Society of America, April, 1894.



TAPESTR ONYX.

Cat. No. 60845, U. S. N. M. Yavapai County, Arizona.
Natural size.

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plateaux. The agave, the refreshing plumpness of whose virgin leaves stands out in marked contrast with the dried and shrunken forms of the flower-bearing adults, forms, together with the thorny *Fouquieria splendens*, the most striking floral feature of the waterless land. The onyx occurs in the form of spasmodic and isolated patches, sometimes forming apparently a superficial pavement upon the surface, or again, where the beds have been cut by the winding course of the now dry ravine in the form of three distinct layers, from 20 inches to 3 or more feet in thickness, interstratified with tufaceous and lake bed material. (Pl. 16).

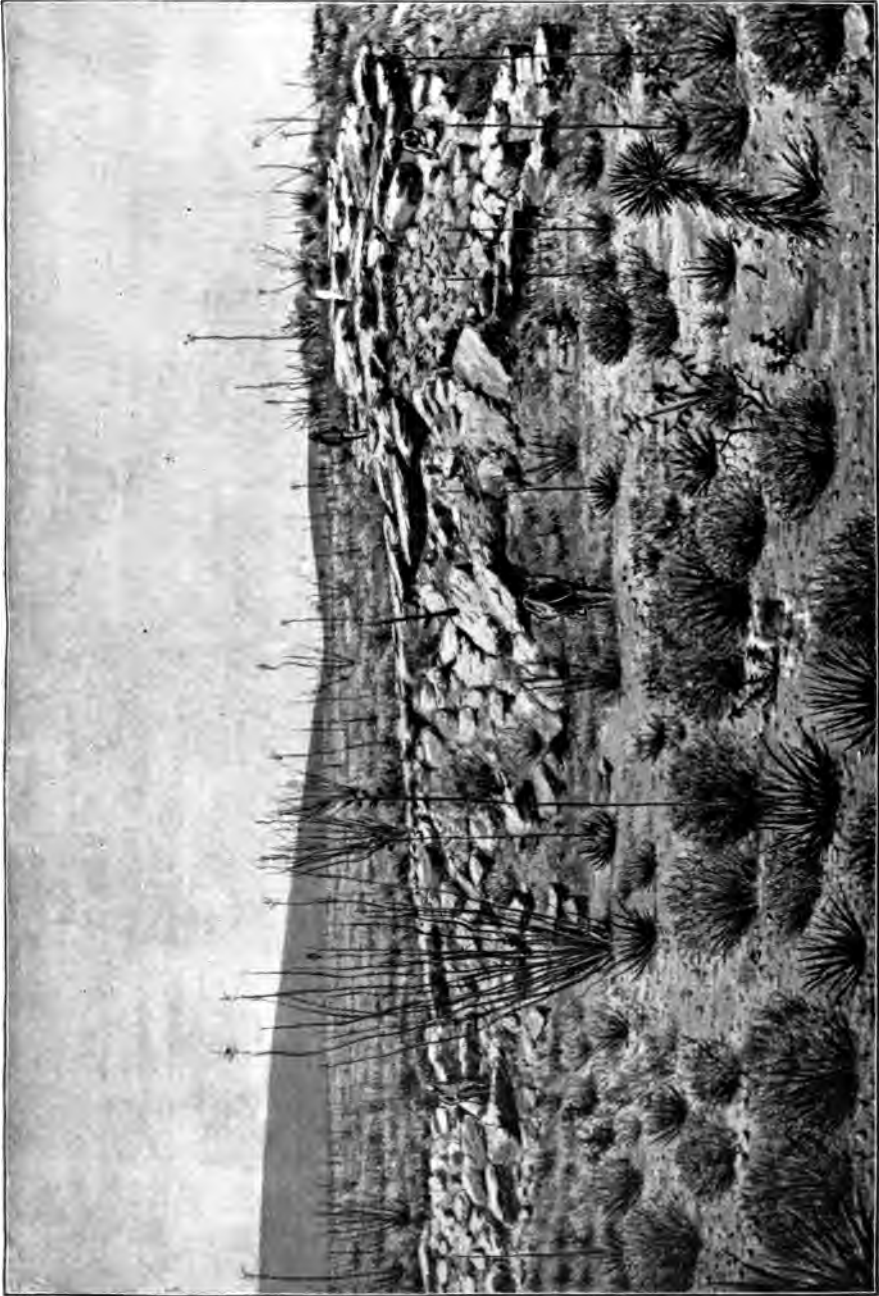
Nothing can be more fascinating to the lover of the beautiful in stones than this occurrence, where huge blocks of material of almost ideal soundness, with ever varying shades of color and veination lie everywhere exposed in countless numbers. Under the blistering sun of an almost tropic climate the exposed blocks have become to some extent corroded, and covered upon their immediate surface with a thin film of oxidation products which just sufficiently disguise the true color and translucency to keep one running here and there, ever cracking off new fragments in the vain attempt to collect a fairly typical series. The colors are peculiarly delicate, and there is a wonderful uniformity in quality. Pearl white (the virgin onyx), delicate rose tints, and light greens are the more common, all variegated by a network of fine sharp veins of a rose-red color, as shown in Plates 17 and 18. The rose color is, so far as my present knowledge goes, quite unique and wonderfully beautiful.

The analyses given in the table show this to be the most dense of any of the onyx marbles thus far examined. Although less highly colored than some of the Mexican varieties, it is nevertheless one of the most beautiful, owing to its uniform translucency, freedom from flaws, and fine veination.

Algeria.—The celebrated deposits from whence the ancient Romans drew their supplies of onyx, alabaster, calcareous onyx, or oriental alabaster are situated in the northern part of Algeria, in the province of Oran. The deposits as now worked are two in number, one some 65 miles from Oran, on the route to Tlemcen, and the second a few miles to the west, both lying to the right of the Isser. The first of these, known by the name of Bled Bekham, is divided into three parts by two ravines, the Oued Abdallah on the east and the Oued Calkra on the west. M. Comynét estimates the area occupied here by the onyx as about 12 acres, and gives the following section: (1) A bed of about 4 feet thickness, under which lies compact travertine of no value; (2) a second bed of onyx 3 feet 4 inches thick, separated by impure travertine from a third bed of onyx 2 feet in thickness, and lastly, several thinner beds from 6 to 16 inches in thickness, alternating with impure travertine, making in all a mean thickness of some 10 feet of quarryable material. It was stated at the time that blocks of extraordinary size could be quarried for shafts, columns, or friezes,

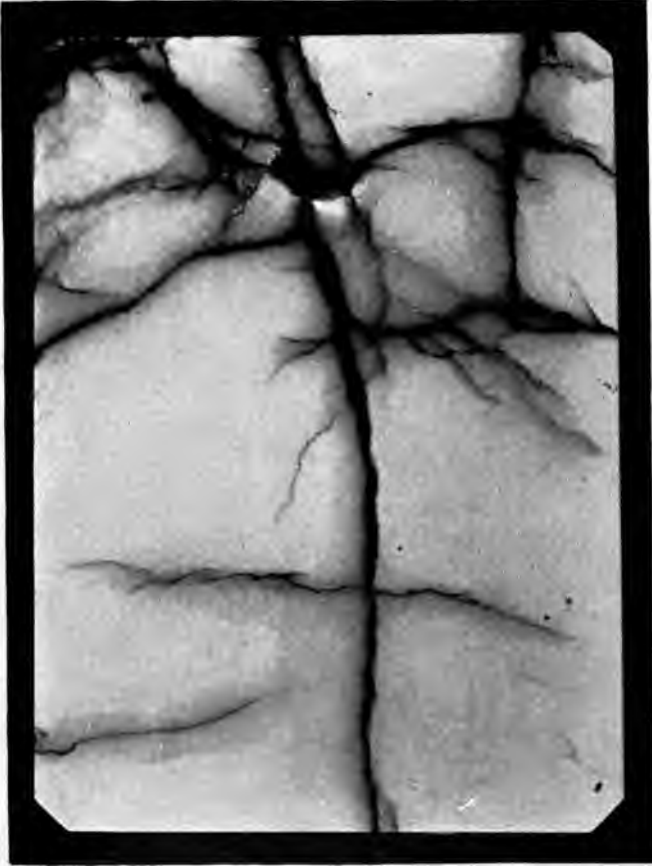
even up to 20 feet in length by 4 feet square. At this date it is stated blocks may be had 10 feet in length by 3 feet in width and thickness. The second deposit noted, called Ardja-el-Beida, lies some 3 kilometers to the west of Bled Bekham, upon a plateau with steep north, west, and south escarpments. It was once continuous with a bed called El Cellon, but from which it has become separated by a ravine called the Chabbat-Karonba. The onyx of this locality is said to be inferior to that of the first, both as regards quality and size of blocks obtainable. The beds vary in thickness from 30 inches with a total of some 10 feet, and cover an area of about 20 acres. All the deposits are Quaternary, and lie unconformably upon lime and sandstones of Tertiary (Middle Miocene) age. The stone, as is usually the case, varies greatly in color and shade, from pure white to rose-colored and bright red, golden yellow, and, more rarely, green. The present quarriers (Sauville & Co., Paris) divide the output into four classes, *le Blanc*, *le Rubauné* or *Veiné*, *le Cachemire* and *le Cachemire bois*. The white (blanc) variety is the more abundant, and is found in nearly all the quarries, occurring in layers sometimes upward of a meter in thickness, and blocks have been removed containing upwards of 5 cubic meters. It varies from translucent to opaque, sometimes milk white or veined with fine ribbons of pale yellow. The milk-white variety is employed for columns, articles used in religious ceremonies, and in place of ordinary white marble in furniture. The translucent variety is employed in statuary, and has, besides, many other applications, as for the glazing of church windows and for shades. The ribboned or veined onyx is also abundant, and there are many places for its extraction. The ribbons are parallel with the plane of deposition, and of a clear deep yellow, sometimes rose or violet tint. Other irregular veins traverse the stone in all directions, giving very beautiful effects. This variety is also obtainable in blocks of good size, and is used for buildings, columns, pilasters, balustrades, stairways, panels, or for furniture tops. A green variety also occurs, though now somewhat sparingly. The prevailing color is paler than the better varieties of the Mexican or American stone. A rose variety, said to have been especially admired by the Romans, is found in small blocks, scarcely larger than a paving stone. White translucent varieties with irregular veins of lively red or orange yellow also occur, though sporadically and in small masses.*

* In a publication entitled "Notice Mineralogique par le Service des Mines" (Algeria, 1889) I find references to onyx quarries as below: In the province of Oran, at Ain Seboa, some 17.5 kilometers south 32° west from Nemours, an onyx of yellow, gray, and vermilion tint, apparently belonging to the Quaternary period and resting upon Oxfordian beds; at Sidi Brahim, 10 kilometers south 4° west of Nemours, a similar stone, but of poorer quality, and at Tekbalet, 26 kilometers north 21° east from Tlemcen, a very beautiful variety of diverse hues intercalated in isolated Quaternary areas resting upon Miocene; in the province of Constantine, in Oued Zergua, some 40 kilometers southeast of Souk-Ahras, a marble approximating onyx occurring in veins in Cenomanian beds. This doubtless a stalagmitic or stalactitic deposit.



DEPOSITS OF ONYX MARBLE IN DESERT SOUTH OF SAN QUENTIN, LOWER CALIFORNIA.

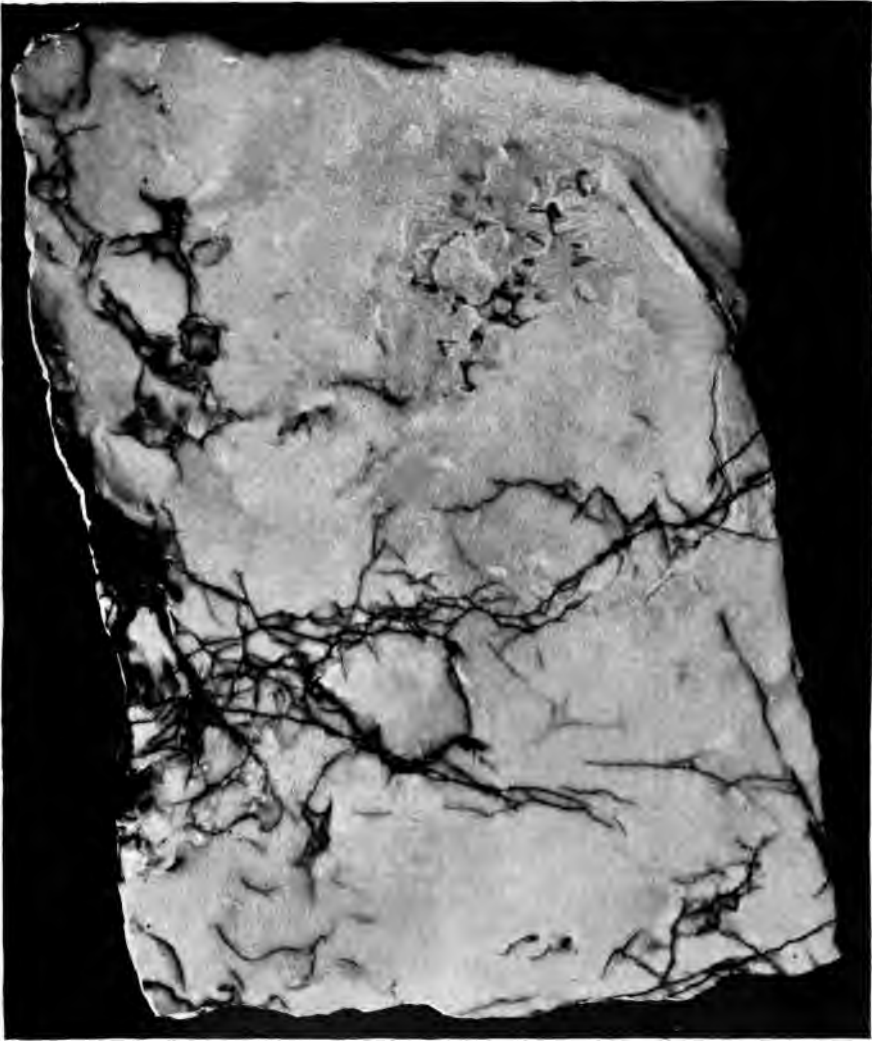
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BLOCK OF ONYX MARBLE FROM LOWER CALIFORNIA.

Natural size.

Colors greenish-white and rose tinted with red-brown veins.



SLAB OF ONYX MARBLE SHOWING SHARP RETICULATING VEINS.

Cat. No. 61388, U. S. N. M. Peninsula of Lower California.

Natural size.

Colors whitish, rose tinted, with red and brown veins.



Although not described in the published accounts, it is evident that a process of oxidation has gone on in certain layers of the Algerian stone, as in that of Arizona, for such material is found in the shape of turned columns and stands for statues and other ornaments in the art and furnishing shops. The colors are quiet ocher and mahogany brown, clouded and veined, and though not as translucent and highly lustrous as objects of the unoxidized stone, such are by no means lacking in beauty. The dealers, in their ignorance of the nature of the materials they handle, will almost invariably assure a customer that such are not of onyx, but "marble," even though as the writer has shown them, there may still be veins or layers of unoxidized material running through them.

Egypt.—Unlike the onyx of Algeria, that of Egypt, at least so far as the better known locality is concerned, is stalagmitic, that is to say, a cave deposit.

According to various authorities* there are two known sources of stone, the first near Beni-Souef, some 25 leagues south of Cairo, and the other at Syout, farther to the south, but also in the Nile Valley. The writer is informed by Dr. Ernest Sickenberger, of Cairo, that the stone of the first-named locality is found in cavities and clefts in Eocene limestone at Gebel Oorakem (Wady Sanoor) east of Beni-Souef, and in smaller amounts east of Assiout. That used in the mosque of Mehemet Ali, as already noted, was taken from the Gebel Oorakem quarries, as was also the material for the beautiful monolithic columns of the Church of S. Paolo fuori le Murs, at Rome. Samples of this stone kindly sent to Washington by Dr. Sickenberger were of a nearly white or only faint straw color, of a granular texture, and in no way remarkable for their beauty, but such as might be duplicated by the hundreds of tons from the broken-down caves in the Silurio-Cambrian limestones of the Shenandoah Valley of Virginia. Mineralogically the stone is calcite and carries only a trace of organic matter in the way of impurities. According to Delesse this deposit was worked by the Egyptians at a very early date, and later by the Romans. As, however, published accounts speak of the stone only as "Egyptian alabaster," we have in most cases no means of ascertaining the exact locality from whence it was derived. The Syout stone differs from that of Beni-Souef in having a micro-radiating instead of granular structure, and in being of a light yellowish or straw color. It is translucent and close in texture, and has a beautifully mellow and pleasing tint either when carved or polished. The date at which these latter deposits were first opened can not be ascertained from available literature. Delesse states, and after him Chateau,† that they were discovered by Selim Pacha, to

* See Delesse, *Materiaux de Construction de L'Exposition Universelle de 1855*; Zittel, in *Baedeker's Guide to Lower Egypt*; Sir J. W. Dawson's *Notes on Useful and Ornamental Stones in Ancient Egypt*.

† *Op Cit.*

whom they were conceded by the vice roi. Boscawen,* however, gives us to understand that they were worked at a much earlier period by kings of the sixth dynasty (3703 B. C. according to Mariette; 2744 B. C. according to Prof. Lepsius). He describes the quarry as situated in the hills to the east of the Siout road, some 10 miles south-east of the plain of Tel-el Amarna, and as being about 250 feet long by 50 feet in width, cut into the face of the hill. It was worked, he says, upon a most regular system, layer after layer being cut away, the product being both "alabaster" and ordinary limestone. The detailed description of this author is as follows:

"Starting from the quarry is a broad roadway, from 15 to 20 feet wide, crossing the hills into the line of the Siout road, and thence across the plain of Tel-el-Amarna to the Nile. This roadway is a wonderful piece of engineering work. In one place a ravine some 40 or 50 feet is crossed, the roadway being carried across by a solid causeway built by bowlders so arranged on a road basis as to support very heavy weights. The gradients are regulated with great care.

"This quarry does not seem to have been worked much during the later dynasties of the Middle Empire. The other day the Arabs brought us news of a large magharah, or quarry, with inscriptions, situated one day's journey into the desert. So Mr. Newberry and myself started on camels. It was a long, dreary ride across the plain of Tel-el-Amarna, along the Siout road, and across the hills, slightly to the south of Hat-Nub. Here we crossed a number of barren wadies and reached the slopes of a low limestone range, probably the northern portion of the Jebel-Kaiwleh, and after a hard climb reached the entrance to a large quarry, which was partially blocked with drift and rubbish. It required but a very casual inspection to find that we had struck a very ancient quarry, for on the lintel of the door were a number of inscriptions of King Teta, the founder of the sixth dynasty. The inscriptions on the doorway were very archaic in type, especially the rudely-drawn figures of a dog and a hawk and the portrait of Teta wearing a crown. The entrance chamber of the quarry ran due south for a distance of about 80 feet and then struck a broad isle running slightly southeast for a distance of about 110 feet. All around were fragments of beautiful alabaster, of a type not used for building purposes, but the fine, rich, yellow, close-grained sort, often with brown veins, used for statues, vases, and toilet and sacrificial pots. The walls were covered in many places by rude votive inscriptions, usually painted panels representing a sacrificial scene, with the table of offerings. Some of these are grotesque almost to caricature. The face and limbs are the dark Egyptian red, the robe white, while the grotesque nose of the figure and the green palm branch seem to quite burlesque the scenes near. Over the figure is a short hieratic inscription. On other walls are dated inscriptions in the reign of Amenemhat II, of the twelfth dynasty, and a fine rock-cut tablet of Usertesen III. The king is here represented seated on his throne, with his hunting dog by his side.

"The quarry does not seem to have been worked after the period of the twelfth dynasty. We slept in the quarry that night, and it was indeed about as old and as weird a bedchamber as was ever my fortune to occupy. Bats flew over our heads and blinked at the lamp, and about midnight two foxes, whose home we had usurped, came to the top of the neighboring hills and barked defiance. * * * The morning was devoted to examining the quarry, and with some interesting results. The alabaster vein was not very thick, but very rich in color, and the method of working seemed to have been to cut out blocks about 4 or 6 feet long and 3 feet in depth and width. These were hewn out and roughly dressed with stone hammers and chisels made

* See Stone, Indianapolis, Indiana, Sept., 1893, pp. 362-365.

from hard bowlders. * * * The hands were protected by hide bands wound around the chisel, and several strips were found in the débris. That the alabaster from this mine was only transported in small portions is shown by the fact that there is no made roadway for sledge transport.

“Another alabaster quarry remains to be mentioned, situated to the east of the Tel-el-Amarna plain, behind the northern tombs. This was worked by Rameses II and his son Meneptah, the Pharaohs of the Oppression and the Exodus, and its steep sides may have echoed to the blows of the picks of the toiling Israelites.”

Persia.—The onyx found in the vicinity of Lake Oroomiah has already been referred to in discussing the origin of this class of rocks. For a description of its mode of occurrence we have to rely mainly upon the accounts of travelers who are neither chemists or geologists. The writer is informed by Mr. P. Z. Easton that the quarries, if such they can be called, lie not far from the main road from Tabriz to Maragha, about 44 miles from the former place and 28 miles from the latter. I find two somewhat detailed accounts of the occurrence in the literature at hand, and venture to give both in full, though the first more as a curiosity than as a contribution to scientific knowledge. This is by Morier * and is as follows:

“On the 24th we proceeded to Shirameen, a village near the lake, and distant 3 fursungs from the preceding stage. At the distance of 1 fursung on the right of the road is a spring of chalybeate water, and 2 fursungs farther on, after having discovered the expanse of the lake, we diverged from the road to visit the petrifications.

“This natural curiosity consists of certain extraordinary ponds or slashes whose indolent waters, by a slow and regular process, stagnate, concrete, and petrify, and produce that beautiful transparent stone commonly called Tabriz marble, which is so remarkable in most of the burial places in Persia, and which forms a chief ornament in all the buildings of note throughout the country. These ponds, which are situated close to one another, are contained in a circumference of about half a mile, and their position is marked by confused heaps and mounds of the stone, which have accumulated as the excavations have increased. We had seen nothing in Persia yet which was more worthy of the attention of the naturalists than this; and I never so much regretted my ignorance of subjects of this nature, because I felt that it is of consequence they should be brought into notice by scientific observation. However, rather than omit all description of a spot which perhaps no Europeans but ourselves have had the opportunity of examining, and on which, therefore, we are bound (in justice to those opportunities) not to withhold the information which we obtained, I will venture to give the following notes of our visit, relying upon the candor and the science of my reader to fill up my imperfect outline.

“On approaching the spot the ground has a hollow sound, with a particularly dreary and calcined appearance, and when upon it a strong mineral smell arises from the ponds. The process of petrification is to be traced from its first beginning to its termination. In one part the water is clear, in a second it appears thicker and stagnant, in a third quite black, and in its last stage is white, like a hoar frost. Indeed, a petrified pond looks like frozen water, and before the operation is quite finished a stone slightly thrown upon it breaks the outer coating, and causes the black water underneath to exude. Where the operation is complete a stone makes no impression, and a man may walk upon it without wetting his shoes. Whenever the petrification has been hewn into the curious progress of the concretion is clearly seen, and shows itself like sheets of rough paper one over the other in accumulated layers. Such is the constant tendency of this water to become stone

* Morier, *Second Journey through Persia*, May 18, 1818, pp. 284–286.

that where it exudes from the ground in bubbles the petrification assumes a globular shape, as if the bubbles of a spring, by a stroke of magic, had been arrested in their play, and metamorphosed into marble. These stony bubbles, which form the most curious specimens of this extraordinary quarry, frequently contain within them portions of the earth through which the water has oozed.

"The substance thus produced is brittle, transparent, and sometimes most richly streaked with green, red, and copper-colored veins. It admits of being cut into immense slabs, and takes a good polish. We did not remark that any plant except rushes grew in the water. The shortest and best definition that can be given of the ponds is that which Quintus Curtius gives of the Lake Ascanius, "Aqua sponte concreescens" (Lib., XI., c. 12). The present royal family of Persia, whose princes do not spend large sums in the construction of public buildings, have not carried away much of the stone; but some immense slabs which were cut by Nadir Shah, and now lie neglected amongst innumerable fragments, show the objects which he had in view. So much is this stone looked upon as an article of luxury that none but the king, his sons, and persons privileged by special firman are permitted to excavate; and such is the ascendancy of pride over avarice that the scheme of farming it to the highest bidder does not seem to have ever come within the calculations of its present possessors."

The second account, that of Curzon,* is apparently the more accurate, though he also refers to the stone as a "petrification," and is quite in error in stating that the springs in the Yellowstone Park have deposited "gleaming blocks of snow-white marble." He says:

"Near the eastern shore of the lake (Oroomiah), and at about 6 miles from the village of Dehkharegan, are the pits or springs from which is extracted the famous semitransparent marble, sometimes called after the neighboring town of Maragha, sometimes after Tabriz. A number of springs, clustered within an area of half a mile in circumference, are constantly bubbling up and precipitating the limestone which they hold in solution. This is deposited in the form of horizontal layers, which are like a thin crust to start with, and can be cracked or broken, but which gradually solidify into hard blocks, with an average thickness of 7 or 8 inches, the best of which are believed to have been formed when the springs had a much higher temperature than the present (65° F.). When quarried this petrification can be sawn either in the thinnest plates, when it is nearly transparent, and is sometimes used for windows, or in more substantial slabs, in which form it is much used for pavements and mural wainscotings. It is a singularly beautiful substance, being of a pink or greenish or milk-white color, streaked with reddish or copper-colored veins (from the oxide which it contains); and I have seen beautiful samples of it in the palaces and mosques of the East. I have very little doubt that the wainscotings of the Gur Amir, or Tomb of Timur, at Samarkand, which I have described in my former work, and which has puzzled all travelers, is composed of this marble, which there is nothing more natural than the great conquerer should have carried home with him at the close of his Persian campaign.† The process of petrification bears a marked resemblance to that which was in existence till the great eruption of a few years ago at the pink and white terraces in New Zealand, and to that which may still be seen at the Mammoth Hot Springs in the Yellowstone Park, in North America, where the induration may be observed through all its stages, from a film-like frosted sugar to gleaming blocks of snow-white marble."

The Tabriz stone seems to have formerly been quite extensively used

* Curzon, G. N., *Persia and the Persian Question*, etc., Vol. I, 1892, p. 264, *et seq.*

† In footnote to above statement he says: "Since writing the above I have come across the statement as a matter of fact that Timur took back with him to Samarkand a large supply of the marble of Azerbaijan."

by the wealthier classes, as already noted (p. 556), and is still utilized to some extent, though mainly in the manufacture of small ornaments.

The Museum collections contain but a few small pieces of material from this source, and which are either pure milk white in color and very translucent (62609), or of a dull red brown color and opaque (62610), the latter being apparently an oxidation product from the white. The stone is interesting from a chemical standpoint, as already noted (p. 559).

Other localities than those mentioned above are known. Thus Blandford* says:

"Mount Kuh Hazar,† lying between Bam and Karman, consists mainly if not wholly of volcanic rocks and ash beds. At the base of the mountain, near Rayin, there is much calcareous tuffa in horizontal beds, apparently deposited by springs, some of which are seen a short distance up the side of the mountain, forming calcareous deposits. Large blocks of massive carbonate of lime of a slightly greenish tint, and apparently formed in stalagmitic masses, are found in the neighborhood, and are used for ornamental purposes. A similar stone is said to be brought from Yezd and other places, and it is generally known in Persia as Yezd marble. It closely resembles the Egyptian stone known as oriental alabaster, except that the color is greenish white instead of yellow."

This is doubtless the stone described by Curzon as—

"An excellent yellow, semitransparent marble, quarried in the mountains near Yezd, the actual spot being Turun Pusht, 40 miles from Taft and 56 miles from Yezd. As already noted, it is from the Yezd stone, according to Curzon, that was constructed the tomb of the poet Hafiz. From this stone, too, according to the same authority, were constructed the superb marble throne and the twisted marble pillars that now adorn the throne room or talar in the royal palace at Teheran."

Still another locality for this stone or one answering well its description is near the village of Tauris, in Susiane. Chardin‡ describes it as—

"transparent presque comme le cristal de roche, et on voit a travers de tables qui ont un pouce d'epaisseur et meme plus. Ce marbre est blanc, mele de verd, pale comme une maniere de jadde. Il est si tendre que le couteau l'entame: ce qui fait penser a plusieurs que ce n'est pas un vrai mineral, ni qui ait la consistance d'une vraie pierre."

ITALY.—The writer is informed by Chevalier Jervis that very many localities exist in different parts of Italy where natural caverns in limestones of varying geological age are to be met with, and which are capable of affording much fine marble for decorative purposes. A very complete list of these is given in Mr. Jervis's treatise on the economic geology of Italy,§ and we will here mention only the more important and widely known. Singularly enough the ancient Romans, with all their love for lavish display in articles beautiful and rare, seem to have

*Eastern Persia, an account of the Journeys of the Persian Boundary Commission, 1870-1872, Vol. II, p. 486.

†Kuh Hazar is a mountain 14,550 feet in height, lying between Bam and Karman, in the central southern portion of the Empire.

‡Voyages du Chevalier Chardin en Perse, etc., Vol. III, 1811.

§ See I Tesori Sottterranei dell' Italia, vol. 3, p. 340, and vol. 4, p. 504.

worked but little these deposits, but to have preferred bringing their materials from more distant sources. A rich honey-yellow marble of this class occurs in caverns in Archean limestone at Busca, Cuneo province, and may be seen worked up in the royal palace at Turin, and in some of the private houses. It is stated to be very beautiful. A banded dark yellow and white variety, forming a handsome ornamental stone, is found at Indiano Olona, in the province of Como. The stone occurs in caves in Mesozoic limestone not far from the Swiss frontier. At Albino, in the Val Setiana, province of Bergamo, stones of this class may be quarried in slabs of considerable superficial area but limited thickness. It is used for making mantels and other articles of ornament as well as for inlaid work. There are two localities of the stone in the province of Brescia which may be mentioned. One at Pisogne, on the eastern side of the lake of Iseo, where a yellow-brown material is obtained from stalactites in Triassic limestone, and the other at Rezzato, a few miles to the east of Brescia. The stone here is dark brown, and occurs in caverns in the Liassian limestone.

In the Appennine range a large number of localities may be specified where stalactitic and stalagmitic marbles of great variety and beauty are to be found. Special mention must be made of the stone known as *alabastro del Gazzo*, from the fact of its coming from Monte Gazzo, at San Giovanni Battista, province of Genoa, overlooking the Mediterranean Sea. The cave is in a Triassic limestone. The stone is described by Chevalier Jervis as a beautiful and gorgeous material, and as having been largely used in former centuries for internal decoration in the churches of Genoa. A great number of stalactites from the same part of Liguria were employed with wonderfully artistic effect in making the artificial cave in the celebrated gardens of the Marquis Pallavicini, at Pegli, near Genoa. In the province of Siena there is a cavern in Liassian limestone whence large masses of cave marble have been procured for decorative purposes, while at Castelnuova dell' Abbate, in the commune of Monte Alcino, considerable quantities are found underlying a Quaternary travertine. Stones of this same class are found also at Terracina, province of Rome, and at Gesualdo (principato Utteriore), near the central chain of the southern Appennines. This last locality furnished the architect Vanvitelli 32 monolithic shafts or columns for the royal palace at Caserta. The same stone, together with other marbles, was used by the King of Naples for the internal decoration of the royal palace at Portici, now the higher school of agriculture.

Miscellaneous localities.—According to D'Orbigny and Gente,* France has an abundance of beautiful "calcareous alabasters" in grottoes and caves, but the material is less esteemed than that of Italy, whence the commercial supply was largely obtained.

They also state that a veined, undulated "alabaster" of a beautiful

* Geologie Appliquee aux Arts et a l'Agriculture.

wax yellow color is found in caverns at Malaga, in Spain. When cut across the bedding it shows veins of two very pleasing tints, but when cut parallel it shows only large, confused, cloudy areas (*taches embrouellies*), and is not nearly as beautiful. The Palais at Madrid is decorated with this stone. C. P. Brard, in his *Mineralogie Appliquee aux Arts*, 1821 (p. 396), describes the onyx marbles as cave deposits, and seems never to have heard of their occurrence as hot-spring deposits. Under this head he describes, very briefly, clouded white, limpid to opaque varieties, sometimes of a beautiful green tint, from Arcena, in Andalusia, Spain. The translucent varieties were the soundest and most esteemed by the ancients (whoever they may have been). He also speaks (p. 402) of a honey yellow, almost transparent variety from the isle of Malta, and which was used in making statues of large size. Other varieties are also found on this island, one of a clear yellow color, veined with white, or white variegated with black, or brown and white. This same authority further states that a brown "alabaster" with clearer veins, and which receives a beautiful polish, is found in the territory of Saguna, in Sicily, and near Montreal and Caputa other varieties, with lively red and yellowish veins or clear yellow and white. A white variety with yellow and red veins is found at Mount Pellegrino and a yellowish one at Bactia, in Corsica. Unfortunately, this author's descriptions are meager, and the use of the name alabaster, as already noted, is so misleading that we can not in all cases discriminate, and it is possible some of the stones here mentioned may be true alabaster (gypsum).

Pliny* writes of a white alabaster, which is presumably a true carbonate, as occurring at Damascus, in Syria. He compares it with that found near Thebes (Syout?), in Egypt, but of a white color. The most next esteemed variety, he states, is that of Carmania (Carmona, in Spain?), and the least that of Cappadocia, in Asia Minor. Next to that of Carmania he considers a product of a locality, not mentioned, in India, as of greatest value, and places that of Syria as third in the list.

CATALOGUE OF ONYX MARBLES IN THE COLLECTION OF THE DEPARTMENT OF GEOLOGY
IN THE U. S. NATIONAL MUSEUM.

No. 67549. A series of five slabs, varying from 8 by 10 inches to 28 by 34 inches, cut parallel and across the plane of deposition. Original colors green, but individual slabs showing various stages of oxidation. Three large slabs, 28 by 34 inches, were all cut from the same block, originally some 10 inches thick and supposed to be nearly uniform throughout, but proving to be so thoroughly oxidized in certain portions as to yield slabs with but a few square inches of green still showing on the polished surface. (See pls. 5, 6, and 7). From the Big Bug Quarries, Mayers Station, Yavapai County, Arizona. Collected by George P. Merrill. 1891.

* Pliny, *Natural History*, Book xxxvi, chap. 12.

- No. 62382. Three slabs, of a thin-bedded granular, scarcely translucent variety of travertine of a white, amber, ochreous brown, and red mottled color. Largest an irregular oval some 24 by 38 inches. From Big Bug Quarries, Mayers Station, Yavapai County, Arizona. Collected by George P. Merrill. 1892.
- No. 60845. Slab of opaque oxidized variety "tapestry onyx." Cut across the grain on plane of deposition. Size, 15 by 21 inches. Locality as above. (See Pl. xv.)
- No. 66999. Irregular slab of green and oxidized travertine, some 12 by 36 inches. Cut across the grain. Locality as above. Gift of William O. O'Neill. 1891
- No. 68364. Slab of a pink granular, scarcely translucent variety, 17 by 36 inches, Locality as above. Received from G. S. Fellows. 1892.
- No. 68365. Irregular slab, 12 by 15 inches, of light green and brownish material. Locality as above. Received from G. S. Fellows. 1892.
- No. 67825. Small irregular block about 5 by 9 by 2 inches. Selected to show nuclear mass of unchanged green onyx surrounded by a shell of oxidized material. (See Pl. 8.) Locality as above. Collected by George P. Merrill. 1892.
- No. 60846. Three irregular slabs, the largest some 22 by 26 inches, of opaque oxidized travertine, of ochreous yellow, brown, and red colors. Cut parallel with plane of deposition. Locality as above.
- No. 67000. Three slabs, 5 by 13, 7 by 13, and 5 by 18 inches. Cut across the plane of deposition to show alternating bands of oxidized and unchanged material. Locality as above. Gift of William O. O'Neill. 1891.
- No. 67821. Block about 3 by 4 inches of oxidized onyx, illustrating the completed stage of the process. Locality as above. Collected by George P. Merrill.
- No. 68251. Three blocks, 4 by 7, 8 by 7, and 5 by 7 inches, of green and brown travertine, from the so-called Cave Creek Quarries, in the southern part of Yavapai County, near the Maricopa County line, and some 50 miles north of Phenix, Arizona. Collected by George P. Merrill. 1892.
- No. 61306 and No. 61307. Seven small slabs of white, pink tinted, and smoky clouded varieties, from San Luis Obispo, California. (Pl. 12.) Highly translucent. Received from J. and F. Kessler. 1893.
- No. 36759. Two small thin slabs, 1½ by 3½ inches, of white onyx, cut across the grain. Nearly transparent. Locality as above.
- No. 25571. Two cubes, 4 by 4 inches, of white and white-brown veined travertine, from locality as above. Received from the Tenth Census. 1881.
- No. 27301. Small slab, 3½ by 4 by 1 inches, marked only as from California. Received from Mrs. L. J. Wilkins. 1882.
- No. 36886. Small slab, some 5 by 11 inches, of bright emerald green, highly translucent travertine, from near Crescent Falls of Sacramento River, 5 miles south of Berryville, Siskiyou County, California. Received from J. S. Diller and L. J. Griffin. 1884.
- No. 67665. Two small pieces similar material from Shasta Springs, Shasta County, California. Received from F. W. Crosby. 1892.
- No. 68451. Small irregular fragments of a dark amber variety, cut across the grain. From Sulphur Creek, Colusa County, California. Received from Henry S. Durden. 1892.
- No. 25255. Slab of dark amber variegated travertine, 5 by 10 inches, from Suisun City, Solano County, California. Received from Centennial Commission. 1876.
- No. 25256. Slab of dark amber variegated travertine, 5 by 10 inches. Locality as above. Received from Centennial Commission. 1876.
- No. 38445. Five small irregular pieces of dark amber variegated travertine, cut across the grain and polished. Locality as above. Received from B. K. Emerson. 1886.
- No. 25645. One small piece of dark amber variegated travertine, 6 by 6½ by 2 inches cut across the grain and polished. Locality as above. Received from the Tenth Census. 1881.

- No. 16054. One small piece of dark amber variegated stone, 5 by 7½ inches, cut across the grain and polished. Locality as above. Received from Thomas Donaldson.
- No. 25374. Block of translucent stalagmitic marble, 3½ by 4 by 5 inches. From the Luray Caverns, Page County, Virginia. Received from R. R. Corson. 1881.
- No. 67981. Massive stalagmite cut in half and polished to show structure. Locality as above. Received from J. H. Morrison.
- No. 60693. Irregular slab of translucent stalagmitic marble, of light, amber color, about 12 by 14 inches. Suisin, Solano County, California. Received from H. A. Ward. 1893.
- No. 60694. Irregular slab about 3 by 2 feet by 1½ inches of dark amber variegated travertine, cut with the grain and polished. Locality as above. Obtained from H. A. Ward.
- No. 25637. Block of translucent stalagmitic marble, coarsely crystalline, almost granular, light amber yellow, 7½ by 10½ by 14½ inches. Luray, Virginia. Received from R. R. Corson. 1881.
- No. 62072. Slab of nearly white, faintly translucent stalagmitic marble, from broken-down cave near Marion, Smyth County, Virginia; 15 by 16 inches. Received from Dr. John S. Apperson. 1893.
- No. 67366 and No. 67366a. Two slabs and large block of dark amber and brown, scarcely translucent stalagmitic material, cut across the grain, and showing concentric structure, from farm of G. H. Killinger, Marion, Smyth County, Virginia. About 12 by 18 inches and 18 by 18 inches. Received from F. V. Z. Carachristi. 1891.
- No. 68131. Slab of nearly white stalagmitic material, from cave near Andersonville, Tennessee. Cut across the grain. Received from W. H. Evans & Sons. 1892.
- No. 60624. Cross section of stalagmite, some 7 inches in diameter, translucent, from Wyandotte Cave, Wyandotte, Indiana. Collected by George P. Merrill. 1893.
- No. 68144. Two massive stalagmites cut and polished to show structure. Locality as above. Collected by George P. Merrill.
- No. 60625. Turned ornament of stalagmite, some 7 by 11 inches; light, amber colored; translucent. Locality as above.
- No. 68126. Irregular blocks, polished on one side, of stalagmitic material, from broken-down caves near Harrisonburg, Rockingham County, Virginia. White and amber. Received from F. Staling.
- No. 67583. Slab of stalagmitic material, cut across the grain; 10 by 12 inches. Locality as above. Gift of J. S. Moffett. 1892.
- No. 68188. Conical block, about 8 inches at base and 9 inches in height, of red, brown, and white stalagmite, from cave at West Plains, Howell County, Missouri. Gift of W. P. Davis. 1892.
- No. 60699. Slab of opaque, dark amber brown stalagmite, from cave in Crawford County, Missouri; 25 by 27 inches. Received from J. F. Leighton. 1893.
- No. 67913. Irregular blocks of faintly greenish stalagmitic material, from caves in the Stevenson-Bennett mines, west slope of Organ Mountains, near Las Cruces, New Mexico. Collected by George P. Merrill. 1892.
- No. 61404. Large rough block of white, scarcely translucent stalagmitic material, from Marion County, Arkansas. Received from State Commissioner World's Columbian Exposition. 1893.
- No. 67617. Finely banded irregular travertine of white color, from about 12 miles southwest of El Paso, Texas; 8 by 3 inches. Received from F. W. Crosby. 1892.
- No. 67618. Small block of finely banded pearl white travertine (?), with ocherous veins, from near El Paso, Texas; 3 by 5 by 1½ inches. Received from F. W. Crosby. 1892.
- No. 61405. Polished slab, 24 by 36 by 2 inches, of dark amber and whitish material, from near Las Vegas, Valencia County, New Mexico. Received from T. B. Mills. 1894.

